JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVI, No. 3. 73D YEAR. SEPTEMBER, 1898

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

CHEMICAL SECTION.

Stated Meeting, February 15, 1898.

THE CHEMICAL COMPOSITION AND TECHNICAL ANALYSIS OF WATER GAS.

BY EDWARD H. EARNSHAW.

Chemist to the United Gas Improvement Company, Philadelphia, Member of the Institute.

As is well-known, water gas is a product of the reaction between steam and incandescent carbon, whereby there is formed a mixture of carbonic oxide and hydrogen in approximately equal volumes. This mixture, technically called "blue gas," has of course no illuminating value, and it is therefore enriched by exposing it together with hydrocarbon vapors to the action of intense heat. The hydrocarbon vapors are thus permanently gasified, or "fixed," and impart a high illuminating power to the mixture. This is carburetted water gas, more familiarly known simply as water gas.

The enriching material employed is always petroleum in some form, usually as crude oil, naphtha, or a distillate

called gas oil, which during the "fixing" process is converted into hydrogen and gaseous hydrocarbons, together with naphthalene, benzene and its homologues, and the other pungent empyreumatic compounds found in coal gas, and formed in that case by the contact of the gas with the hot sides of the retorts. The odor of coal gas is due to these empyreumatic compounds, and therefore, as might be expected, the odor of water gas is similar, but even more penetrating.

The chemical composition of coal gas and water gas is essentially the same; that is to say, the same constituent gases enter into the composition of each mixture, but the relative proportions vary. This is illustrated by the following analyses of coal gas and water gas respectively. The figures given are of actual analyses, but are fairly representative of each class:

	Coal Gas. Per Cent.	Water Gas. Per Cent.
Benzene vapor	0·50	0·6
Heavy hydrocarbons	4·25	12·8
Carbonic oxide	8·04	30·7
Hydrogen	47·04	32·4
Marsh gas	36·02	13·9
Higher paraffines	0·00	2·4
Carbonic acid	1·60	2·7
Oxygen	0·39	0·7
Nitrogen	2·16	3·8
	100·00	100·00

The composition of the heavy hydrocarbons, or "Illuminants" varies greatly with circumstances, both with coal and water gas, though they always consist chiefly of ethylene and other members of the olefin series, together with small quantities of other hydrocarbons of which acetylene is probably the most important.

From the gas analyst's point of view, the most important feature of the composition of water gas is the presence of notable quantities of paraffines other than marsh gas, since this involves a modification of the methods of analysis commonly in use, and which presuppose that marsh gas is the only paraffine present in the gas mixture.

This is the point that I chiefly desire to bring to your attention to-night.

THE ANALYSIS OF WATER GAS.

The scheme of analysis, as far as the absorbable constituents of the gas mixture are concerned, follows the plan elaborated by Hempel, and is as follows:

(1) The vapors of benzene are first absorbed by shaking the gas in an explosion pipette over mercury with 1 c.c. of alcohol, previously saturated for the less easily absorbable constituents. The vapor of alcohol is absorbed in another explosion pipette by 1 c.c. of water, and the resulting contraction measured.

(2) The carbon dioxide is absorbed by potassium hydrate in a pipette filled with small rolls of iron wire gauze.

(3) The heavy hydrocarbons, or fixed illuminants are absorbed by a saturated aqueous solution of bromine. The vapors of bromine are absorbed by potassium hydrate, and the contraction measured.

Fuming sulphuric acid may be used instead of bromine, but it is much more difficult and inconvenient to handle, and the results obtained are scarcely more accurate.

(4) Oxygen is absorbed by phosphorus. Some chemists urge the use of an alkaline solution of pyrogallic acid, claiming that the action of phosphorus is unreliable. I have found, however, that in every case where the phosphorus has failed to act it has been due to incomplete absorption of the illuminants. Therefore, whenever on testing for oxygen, the white fumes of phosphoric acid fail to appear, the gas should be passed once more into the bromine solution. I have never yet analyzed a gas that did not contain at least a trace of oxygen. I strongly favor the use of phosphorus because the results obtained are at least as accurate as with pyrogallol, and because the appearance of the white fumes is absolute proof of the presence of oxygen, and indicates as well that the illuminants have been completely absorbed.

(5) The carbonic oxide is now absorbed by an ammoniacal or hydrochloric acid solution of cuprous chloride.

At least two pipettes should be used for the absorption, the last one containing a perfectly fresh solution. It is important to notice that even with this precaution the absorp-

tion of the carbonic oxide is seldom complete, usually about 0·5 per cent. remaining unabsorbed. This fact introduces no error in the analysis, as this residue of carbonic oxide can be determined later, as will be shown.

The residue of the gas mixture now remaining may be as follows:

(a) $(H_2) + (CO) + (N_2) + (CH_4) + (C_2H_6) + (C_3H_8)$, etc.

But for all ordinary purposes it is sufficient to assume that the only higher paraffine present is C_2H_6.

There being no satisfactory known absorbent for any of these gases it becomes necessary to have recourse to the method of combustion.

A portion of "a" is then mixed with a measured volume of air and exploded over mercury in an explosion pipette. The contraction in volume is measured, the carbon dioxide formed is determined by absorption with potassium hydrate, the excess of oxygen absorbed by phosphorus, and the volume of the residual N is noted.

The equations are:

(1) Contraction in volume $= \frac{3}{2}(H_2) + \frac{1}{2}(CO) + 2(CH_4) + 2\frac{1}{2}(C_2H_6)$

(2) CO_2 formed $= (CO) + CH_4) + 2(C_2H_6)$

(3) Residual nitrogen $= (N_2) + (N_1)$,

where N_1 is the nitrogen introduced with the air. The amount of nitrogen thus introduced may with sufficient accuracy be taken at 79·2 per cent. of the measured volume of air.

An examination of these equations shows that the nitrogen may at once be ascertained from equation (3), but equations 1 and 2 contain four unknown quantities, and therefore two more equations are needed for the solution. Fortunately the method of fractional combustion over palladium affords the needed information. As is well known, when a mixture of hydrogen and CH_4 with oxygen or air is passed with the proper precaution over heated palladium black, the hydrogen burns to H_2O, but the CH_4 is unaltered. If CO and any of the higher paraffines are also present, the

CO burns, but the paraffines do not. If then, the products from the combustion are received in a pipette over mercury, it is possible to subsequently measure the amount of CO_2 formed by the burning of the CO.

Returning to the analysis, a second portion of (a) is taken, mixed with air, and burned over palladium black. The resulting contraction and the CO_2 formed are measured. The equations are:

(4) Contraction in volume $= \frac{3}{2}(H_2) + \frac{1}{2}(CO)$.

(5) CO_2 formed $= CO$.

From these two equations the values for hydrogen and CO may be readily calculated.

For simplicity's sake let us now assume that the same quantity of gas mixture (a) was used in both the explosion and the combustion. We may then subtract equation (4) from (1), and (5) from (2), whence, designating the difference between the contraction due to explosion and that due to combustion by the letter (a) and the difference in the CO_2 formed by the letter (b), we find

(6) $2(CH_4) + 2\frac{1}{2}(C_2H_6) = a$.

(7) $(CH_4) + 2(C_2H_6) = b$.

(8) whence $C_2H_6 = \frac{4b - 2a}{3}$.

(9) $CH_4 = \frac{4a - 5b}{3}$.

A very useful check on the accuracy of this determination is obtained from the following:

Volume of gas taken for explosion $= H_2 + N_2 + CO + CH_4 + C_2H_6$. H_2 and CO are found by (4) and (5), and N_2 is given by (3). Therefore we have,

(10) Volume taken $-(H_2 + N_2 + CO) = CH_4 + C_2H_6$, and this value should be the same as the algebraic sum of (8) and (9), or,

(11) Volume taken $-(H_2 + N_2 + CO) = \frac{2a - b}{3}$.

This scheme of analysis is perfectly correct for gas mixtures containing no higher paraffine than C_2H_6, but what would happen in case C_3H_8, C_4H_{10}, etc., were present?

Our gas mixture would then contain P volumes of hydrocarbons of the formula C_nH_{2n+2}, and would be,

$$\text{Gas mixture} = H_2 + N_2 + CO + P(C_nH_{2n+2}).$$

As will be shown later, the contraction in volume due to the combustion of P volumes of any hydrocarbon of the general formula C_nH_m would be

$$P(1 + \frac{m}{4})$$

and the CO_2 formed would be Pn. But in this case, $m = 2_{n+2}$, and therefore we have,

From the explosion:

(12) Contraction in volume

$$= \tfrac{3}{2}(H_2) + \tfrac{1}{2}(CO) + P + \frac{Pn + P}{2}$$

(13) CO_2 formed $= Pn + CO$.

And from the combustion over palladium:

(14) Contraction in volume $= \tfrac{3}{2}(H_2) + \tfrac{1}{2}(CO)$.

(15) CO_2 formed $= CO$.

Subtracting (14) from (12) and (15) from (13), as before explained, we have,

(16) Difference in contraction

$$P + \frac{Pn + P}{2} = a$$

(17) Difference in CO_2 formed $= Pn = b$; whence,

(18) $$P = \frac{2a - b}{3}$$

(19) $$n = \frac{3b}{2a - b}$$

Equation (18) is identical with (11), and hence it appears that the method is correct as far as the total volume of paraffines is concerned, even though higher paraffines than C_2H_6 are present.

Having thus examined the theory of the analysis by combustion, let us follow the figures of an actual analysis.

The gas was a water gas, enriched by naphtha, and its candle-power was 23·5.

Amount taken for analysis	100·0 c.c.
	Per cent.
C_2H_6 absorbed by alcohol	0·4
CO_2 absorbed by potash	2·7
Illuminants absorbed by bromine	11·7
Oxygen absorbed by phosphorus	0·5
CO absorbed by cuprous chloride	31·7

Of the unabsorbed residue of 53 c.c., 14·05 c.c. were mixed with 87·8 c.c. of air, and exploded by a spark in an explosion pipette over mercury. The resulting contraction in volume was 22·60 c.c. The CO_2 absorbed by potash was 5·30 c.c.; the surplus oxygen absorbed by phosphorus 3·80 c.c.; the residual nitrogen, 70·1 c.c. consisting of nitrogen from the air, 69·50 c.c. and nitrogen from the gas, 0·60 c.c.

A second portion of 30 c.c. was now mixed with 70 c.c. of air and the mixture passed over palladium black to burn the hydrogen and CO.

The contraction in volume was 30·40 c.c.

CO_2 absorbed by potash was 0·40 c.c.

To calculate the percentage of hydrogen, CO, CH_4, C_2H_6 and nitrogen according to the method already theoretically explained we proceed thus:

$$CO = \frac{0{\cdot}4 \times 53}{30} = 0{\cdot}70 \text{ per cent.}$$

$$\text{Hydrogen} = \frac{(30{\cdot}4 - 0{\cdot}2) \times 53}{30} \times \frac{2}{3} = 35{\cdot}57 \text{ per cent.}$$

Now, as 30 c.c. of gas were taken for the combustion and only 14·05 c.c. for the explosion, we must calculate the contraction in volume and amount of CO_2 that would have resulted from the combustion of 14·05 c.c. over palladium; thus:

Contraction in volume would be

$$= \frac{30{\cdot}4 \times 14{\cdot}05}{30} = 14{\cdot}24$$

CO_2 formed would be

$$= \frac{0{\cdot}40 \times 14{\cdot}05}{30} = 0{\cdot}18$$

Subtracting these figures from the results of the explosion, we find,

$$22{\cdot}60 - 14{\cdot}24 = 8{\cdot}36 = a$$

$$5{\cdot}30 - 0{\cdot}18 = 5{\cdot}12 = b$$

and hence, from (8) and (9)

$$C_2H_6 = \frac{20{\cdot}48 - 16{\cdot}72}{3} = 1{\cdot}25$$

$$CH_4 = \frac{33{\cdot}44 - 25{\cdot}60}{3} = 2{\cdot}61,$$

and therefore,

C_2H_6 in original gas

$$= \frac{1{\cdot}25 \times 53}{14{\cdot}05} = 4{\cdot}71 \text{ per cent.}$$

CH_4 in original gas

$$\frac{2{\cdot}61 \times 53}{14{\cdot}05} = 9{\cdot}84 \text{ per cent.}$$

Nitrogen in original gas

$$= \frac{0{\cdot}60 \times 53}{14{\cdot}05} = 2{\cdot}26 \text{ per cent.}$$

Applying equation (11) as a check on the accuracy of the determination, we find:

$$14{\cdot}05 - (9{\cdot}43 + 0{\cdot}60 + 0{\cdot}18) = \frac{2\,(8{\cdot}36) - 5{\cdot}12}{3}$$

or, $3{\cdot}84 = 3{\cdot}86$, which is a difference well within the limit of errors of observation.

In the calculation of this analysis we have assumed for convenience' sake that there are no paraffines present other than CH_4 and C_2H_6. Of course, it is possible and indeed probable, that higher members of the series are actually present, so that while the figures obtained in our calculations truly represent the total quantity of paraffines contained in the gas, yet they may not be true as regards the actual composition. The composition of the average molecule of the paraffines may be obtained from equation (19), thus:

$$n = \frac{15{\cdot}36}{16{\cdot}72 - 5{\cdot}12} = 1{\cdot}32$$

whence the average composition of the paraffines C_nH_{2n+2} would be $C_{1{\cdot}32}H_{4{\cdot}64}$.

The value of this method in giving an accurate conception of the actual composition of a gas mixture, is clearly brought out by comparing the figures just given with those obtained by the more usual methods of calculation.

These methods are: (1) when no combustion over palladium is made, and the hydrogen is determined by subtracting twice the volume of CO_2 formed in the explosion from the contraction in volume, and calling the difference the contraction due to hydrogen. (2) The method recommended by Hempel, who directs that the hydrogen should be determined by combustion over palladium. The contraction in volume due to the percentage of hydrogen thus found, is subtracted from the total contraction due to the explosion, and the remainder is considered to be the contraction due to CH_4, which is, of course, equal to twice the volume of CH_4. Both these methods presuppose that no paraffine other than CH_4 is present, and that the CO has been completely absorbed by cuprous chloride.

	Calculated by method given above.	By method without combustion over Palladium.	By method according to Hempel
Benzene vapors	0·40	0·40	0·40
Fixed illuminants	11·70	11·70	11·70
Carbonic oxide	32·40	31·70	31·70
Hydrogen	35·57	30·34	35·84
Paraffines C_2H_6	4·71	—	—
Paraffines CH_4	9·84	20·00	16·30
Carbonic acid	2·70	2·70	2·70
Oxygen	0·50	0·50	0·50
Nitrogen (by difference)	2·18	2·66	0·86
	1000·00	100·00	100·00

The method without separate determination of hydrogen is the simplest both in method and in apparatus required, and is, therefore, the one in most general use.

In the analysis of water gas by this method, let us consider the equations resulting from the explosion of 15 c.c. of a gas mixture composed of

	c.c.
Hydrogen	10
CH_4	3
C_2H_6	1·5
Nitrogen	0·5
	15·0

The resulting equations would be:

Contraction in volume	$= \frac{1}{2}(H_2) + 2(CH_4) + 2\frac{1}{2}(C_2H_6)$	$= 24{\cdot}75$
CO_2 formed	$= (CH_4) + 2(C_2H_6)$	$= 6{\cdot}00$
Volume of gas taken	$= H_2 + CH_4 + C_2H_6 + N_2$	$= 15{\cdot}0$
Nitrogen	$= N_2$	$= 0{\cdot}50$

At first it would seem that these equations could be easily solved, and that no more data would be required for the correct computation of the composition of the gas mixture. An attempt to solve the equations, however, discloses the fact that the problem is indeterminate, and that the equations can be satisfied by any value of C_2H_6 from 0 to 3.

Thus:

Let C_2H_6	$= 0$,	Let C_2H_6	$= 3$
Then, H_2	$= 8{\cdot}50$	Then, H_2	$= 11{\cdot}50$
CH_4	$= 6{\cdot}00$	CH_4	$= 0{\cdot}00$
C_2H_6	$= 0{\cdot}00$	C_2H_6	$= 3{\cdot}00$
N_2	$= 0{\cdot}50$	N_2	$= 0{\cdot}50$
	$15{\cdot}00$		$15{\cdot}00$

We may perhaps find in this circumstance an explanation for the continued use of this method by many analysts without suspecting the incorrect application to gas mixtures containing higher paraffines than methane. The analysis would always "add up well," and the amount of nitrogen found would be correct.

I have now indicated a method by which we may obtain a very fair idea of the composition of a gas mixture, sufficient indeed, for most purposes. But the use of gas as a source of heat is constantly increasing, and I believe the time is not far distant when the heating value of a gas will be considered as important as its illuminating power. It is therefore extremely desirable to be able to accurately calculate the heating value of a gas from its analysis. The labors of many able investigators, and notably those of Prof.

Julius Thomsen, have supplied us with reliable data concerning the heating value of each of the several combustible gases entering into the composition of illuminating gas, and therefore the problem would offer no special difficulty were it not for the uncertainty regarding the nature of the hydrocarbons removed by bromine, and classed together as "fixed illuminants." We know that these consist chiefly of the series C_nH_{2n}, together with very small quantities of the C_nH_{2n-2} series, but the quantitative separation of the different members is not at present possible within the limits of a technical analysis.

If, however, we should succeed in determining the average composition of the hydrocarbons, and should be able to assign a definite heating value, depending upon such average composition, then the problem would be completely solved as far as its practical application is concerned.

The theory of the combustion of any hydrocarbon or mixture of hydrocarbons, of which the unit volume has the average composition C_nH_m, is as follows:

$$C_nH_m\left(n + \frac{m}{4}\right)O_2 = n(CO_2) + \frac{m}{2}(H_2O)$$

But in practice the

$$\frac{m}{2}$$

volumes of water disappear, and therefore we have,

Contraction in volume

$$= 1 + \left(n + \frac{m}{4}\right) - n = 1 + \frac{m}{4}$$

CO_2 formed $= n$

If we let a = contraction in volume for x volumes C_nH_m

b = CO_2 formed for x volumes C_nH_m then we find,

(20) $$m = \frac{4(a - x)}{x}$$

(21) $$n = \frac{b}{x}$$

It is now apparent that if we can by any means determine the contraction in volume and the amount of CO_2 that would be formed by the combustion of a known volume of the illuminants in a gas mixture, then we will have all the data necessary for the correct computation of the average composition of such illuminants. This can be done very simply and accurately thus:

First absorb the unfixed vapors by alcohol, and the CO_2 by potassium hydrate. The residual gas will have the composition,

$$C_nH_m + CO + H_2 + C_nH_{2n+2} + O_2 + N_2$$

Take a portion of this, mix it with the proper amount of air, and explode the mixture by a spark in the ordinary way. Note the resulting contraction in volume, and the amount of the CO_2 formed.

The contraction in volume will consist of:

(1) Contraction due to C_nH_m,
(2) " " " CO,
(3) " " " H_2,
(4) " " " C_nH_{2n+2},

and the CO_2 formed will consist in like manner:

(1) CO_2 due to C_nH_m.
(2) CO_2 due to CO,
(3) " " " C_nH_{2n+2}.

If, now, we proceed with the analysis and determine the percentage of each constituent by the method already described, we will be able to calculate the contraction due to CO, H_2, and C_nH_{2n+2}, and the CO_2 due to CO and C_nH_{2n+2}. This will give us the contraction in volume and the CO_2 due to C_nH_m alone, and hence the data required.

In practice it is simpler to calculate the correction for the Paraffines and Hydrogen directly from the results of the explosion rather than from the percentages of these gases, but this will be made plainer by considering the actual figures of an analysis.

V. 18

Taking for illustration the same sample of water gas as before, the notes of the analysis would be:

	Cubic Centimeters.	Per Cent.
Amount taken for analysis	100·00	
Residue after absorbing the unfixed vapors and the CO_2	96·90 (a)	

First Explosion.

Portion of (a) taken	12·00	
Mixed with 87·8 cubic centimeters of air and exploded:		
Resulting contraction in volume	16·05	
CO_2 absorbed by potash	10·55	
Excess oxygen absorbed by phosphorus	3·40	
Residue from (a)	84·90	
Fixed Ills. absorbed by bromine	10·25	= 11.70
Oxygen absorbed by phosphorus	0·44	= 0·50
CO absorbed by cuprous chloride	27·78	= 31·70
Residue (b)	46·45	= 53·00

Second Explosion.

Portion of (b) taken	14·05
Mixed with 87·8 cubic centimeters of air and exploded:	
Resulting contraction in volume	22·60
CO_2 absorbed by potash	5·30
Excess O^2 absorbed by phosphorus	3·80

The amount taken for the first explosion was

$$\frac{12}{96{\cdot}9} = {\cdot}1237$$

of the original quantity, and we can, therefore, calculate that it was composed of,

	Per Cent.		Cubic Centimeters.
Fixed Illuminants	11·70 ×	·1237	1·45
Oxygen	0·50 ×	"	0·06
Carbonic oxide	31·70 ×	"	3·93
Residue (b)	53·00 ×	"	6·56
			12·00

The contraction and CO_2 resulting from the explosion of 14·05 cubic centimeters of residue (b) having been determined by the second explosion, we can, of course, readily calculate the results due to the combustion of 6·56 cubic centimeters.

The results of the first explosion can now be tabulated thus:

			CO_2 Cubic Centimeters.	Contraction.
1·45 cubic centimeters	Fixed Ills. (C_nH_m)	gives	4·15	3·56
3·93 " "	carbonic oxide	"	3·93	1·96
6·56 " "	residue (b)	"	2·47	10·53
			10·55	16·05

and hence from equations (20) and (21),

$$m = \frac{4\,(3{\cdot}56 - 1{\cdot}45)}{1{\cdot}45} = 5{\cdot}82$$

$$n = \frac{4{\cdot}15}{1{\cdot}45} = 2{\cdot}86$$

and, therefore, the average composition of the Fixed Illuminants C_nH_m is C 2·86 H 5·82.

Prof. Julius Thomsen in his "Thermo-Chemical Investigations," vol. iv, p. 275, gives the general formula for the calculation of the heat of combustion of any hydrocarbon of the formula C_nH_{2m}, expressed in calories per molecular weight in grams of the hydrocarbon, thus:

$$f = n\ {\cdot}135340 + m\ {\cdot}37780 - a\ {\cdot}14200 + 580.$$

For the olefin series, C_nH_{2n},

$$n = m$$

$$a = n - 1$$

and, therefore, translating the formula into English units, we find for the heat of combustion of any hydrocarbon, or mixture of hydrocarbons of the general formula C_nH_{2n}

$$\text{B.T.U. per cubic foot} = n\,(757) + 70$$

$$\text{B.T.U. per pound} = 20432 + \frac{1900}{n}$$

For the paraffine series, C_nH_{2n+2},

$$m = n + 1$$

$$a = n - 1$$

and, therefore, we find for the heat of combustion:

$$\text{B.T.U. per cubic foot} = n\,(757) + 251$$

$$\text{B.T.U. per pound } 20432 + \frac{53744}{14n + 2}$$

We found the composition of the illuminants to be $C_{2\cdot86}H_{5\cdot72}$, and this approaches so closely to the composition of olefins, that for all practical purposes we may consider the fixed illuminants as belonging entirely to that series.

Therefore, calculating the average heating value of the illuminants from the formula for the olefins, we have:

$$\text{Illuminants, } C_{2\cdot86}H_{5\cdot72} = 2235 \text{ B.T.U. per cubic foot.}$$

We found the average composition of the paraffines to be $C_{1\cdot22}H_{4\cdot64}$, and hence from the formula for the paraffines, the average heating value would be:

$$\text{Paraffines, } C_{1\cdot22}H_{4\cdot64} = 1250 \text{ B.T.U. per cubic foot.}$$

We have shown that the determination of the total amount of paraffines in a gas mixture is not affected by considering CH_4 and C_2H_6 to be the only two members of the series present, and it is also true that the calculation of the heating value is unaltered by the same assumption. This may be shown as follows:

The percentage of paraffines present, and their composition, was found by the analysis to be

$$14\cdot55 \text{ p. c. } C_{1\cdot22}H_{4\cdot64} = 4\cdot71 \text{ p. c. } C_2H_6 + 9\cdot84 \text{ p. c. } CH_4.$$

The calculation of the heating value would be

$$\left.\begin{array}{lll} \cdot1455 \text{ cubic foot } C_{1\cdot22}H_{4\cdot64} \times 1250 = 182\cdot9 \text{ B.T.U.} \\ \cdot0471 \quad " \quad " \quad C_2H_6 \times 1764\cdot4 = 83\cdot1 \\ \cdot0984 \quad " \quad " \quad CH_4 \times 1009 \quad = 99\cdot2 \end{array}\right\} 182\cdot3 \text{ B.T.U.}$$

Thus the result is the same whichever method of calculation is adopted.

The heating values obtained by Prof. Julius Thomsen for the principal constituents of illuminating gas are given in the following table. Thomsen's original figures are

given in calories per molecular weight of the substance in grams, and I have translated these into English units per cubic foot. The temperature of the products of combustion is assumed to be reduced to 18° C. or 64·4° F.:

NAME.	Molecular Formula.	Calories per Molecular Weight in Grams.	B.T.U.'s per Cubic Foot at 60° and 30".
Hydrogen	H_2	68360	326·2
Carbonic oxide	CO	67960	323·5
Methane	CH_4	211930	1009·0
Ethane	C_2H_6	370440	1764·4
Propane	C_3H_8	529210	2521·0
Butane	C_4H_{10}	687190	3274·0
Ethylene	C_2H_4	333350	1588·0
Propylene	C_3H_6	492740	2347·2
Butylene	C_4H_8	650620	3099·2
Acetylene	C_2H_2	310050	1476·7
Benzene	C_6H_6	799350	3807·4

Returning once more to our analysis, the calculation of the heating value of 1 cubic foot of the water-gas would be:

·0040	cubic foot	$C_6H_6 \times 3807{\cdot}4$	= 15·2 B.T.U.
·0170	" "	$C_{2\cdot86}H_{5\cdot72} \times 2235$	= 261·5 "
·3240	" "	$CO \times 323{\cdot}5$	= 104·8 "
·3557	" "	$H_2 \times 326{\cdot}2$	= 116·0 "
·0471	" "	$C_2H_6 \times 1764{\cdot}4$	= 83·1 "
·0984	" "	$CH_4 \times 1009{\cdot}0$	= 99·2 "
·0538	" "	$CO_2 + O_2 + N_2$	= 0·0 "
1·0000			679·8 "

Mining and Metallurgical Section.

Stated Meeting, May 11, 1898.

OLD AND NEW METHODS APPLIED IN PLANNING PIPE-LINES AND PENSTOCKS.

By F. M. F. Cazin, Hoboken, N. J.,
Member of the Institute.

[With a reasonable expectation of approval on the part of all men versed in recent evolution of hydraulics, it may be stated at this time that there has sprung into existence that which may be aptly called modern hydraulics.

The science of mechanics in general, and of hydraulics in special, has been represented amongst the living generation by two schools of extremists. This fact may be plainly shown by quoting from two authors of equally high merit.

R. G. Blaine, Senior Demonstrator and Lecturer in the mechanical engineering department of the City and Guilds of London Institute's Technical College, in the preface to his recently published book on "Hydraulic Machinery," expresses his opinion on the proper method to be followed in treating subjects of mechanics or hydraulics, as follows:

"An attempt is usually made to avoid using the calculus or to disguise its use in the language of so-called elementary mathematics; this course is not altogether free from objections, the proofs given being usually long and not too exact."

John C. Trautwine, in the preface to his "Civil Engineers' Pocketbook," after recommending by name of author some works on matters of engineering, expresses his opinion on the same subject as follows:

"The writer does not include Rankine, Moseley and Weisbach, because, although their books are the productions of master minds, and exhibit a profundity of knowledge be-

yond the reach of ordinary men, yet their language also is so profound that very few engineers can read them; they are but little more than striking instances of how completely the most simple facts may be buried out of sight under heaps of mathematical rubbish."

Modern hydraulics stands midway between these two extremes, thus signalized by two leaders in the field of applied mechanics and hydraulics. The more modern method may be described in but few words. It desists absolutely and completely from accepting as true any alleged fact that cannot be verified by proper test under stated conditions. Hence, it does not make observations, using the spectacles of tradition, but approaches all problems that have not found their solution in a clear, simple, uncomplicated equation of general applicability, resting on clearly stated conditions, with a sceptical mind unbiased by predilection for either calculus or elementary mathematics, but for evident cause avoids the former where the latter are adequate. Hence, its distinctive quality consists in this, that essentially it dives for the true causes of observed effects, and strictly refuses to accept words or names where correct conception is wanting, or to be conteht with explaining specific resistances by specific names without the knowledge of the specific and real cause hidden in a name. And it also is peculiar to such modern mechanics and hydraulics that they make distinction between arbitrary units of measurement, set up by man, and such other units as nature itself has provided.

As products of such modern hydraulics the author may quote:

(1) The equation which measures force (and work, when connected with time), which is of general application, and accounts not only for mass and movement, but for all essential dimensions or qualities of both mass and movement, be the mass solid or fluid; an equation which is uncomplicated by undetermined or uncertain coefficients, and which equation is valid in either the metrical or foot-pound system, when its values are properly expressed in such system, namely, the equation to which the author will of necessity have to refer, and which reads:

$$P = Q\,y\,.\,h = F\,.\,v\,.\,h = F\,.\,\frac{v^2}{2\,g}$$

kilogrammetres or foot-pounds.

(2) The equation which, by the mere substitution of the newly-created value

$$\frac{B}{d}$$

(average section) for F in the same cited equation, and on the basis of an analysis of the effects of continuous displacement, has solved all the until then abstruse problems relating to the movement of a volume of stable form within a medium of yielding form, whether the stable form be represented by a steamship, a balloon or a planet. (Compare this *Journal* for March to May, 1893.)

(3) The equation of equal general applicability, by which the uniform maximum velocity is determined, with which a volume of known length in the direction of motion and of known relative density can fall (move) in a fluid medium, or can fall on this globe in air or water, or in any other medium, and by which the main dimension of the solid may be determined, which a current may move at all or at a stated velocity, an equation general in applicability and precise in conditions, namely, the equation for maximum velocity of fall:

$$C = \sqrt{\delta\,.\,d\,.\,2\,g\,.\,\frac{\delta - 1}{\delta + 1}}$$

(Compare *Transactions* Am. Inst. of Mining Engineers, 1894. "Solids Falling in a Medium," I and II.)

To these achievements this paper is intended to add a fourth one, namely, an equation of equally universal applicability, by means of which the form of channel is determined, which will permit a current to flow in such form and with such velocity as unimpeded nature will impart to it, provided its total fall and one of its sections at a known level be stated.]

Prevailing practice in planning pipe-lines or penstocks resorts to tables, in which the results of experimenting with pipes of uniform section, and relating to quantities ejected,

have been collected, such experimenting covering a very limited variety of heads and of pipe dimensions.

It is true that the results thus obtained have been construed into equations of more or less presumed applicability.

Tables and equations were arranged on the assumption of three different elements or conditions, as influencing or determining the results. On the one hand the maximum quantity of ejection was correctly assumed as the product in volume of the velocity of ejection by the area of the aperture of ejection, and the difference between such maximum volume and the volume actually ejected was considered as *loss* (of head) and is expressed as *percentage of head lost*, or as the first element in the construction of tables and equations. The *loss* ascertained is then ascribed to two different causes, as the other two elements in such construction, namely:

Loss due to the *orifice of influx*, and

Loss due to *friction*.

When the quantity of water to be supplied is known, prevailing practice consults the tables, which, of necessity, are considered as more reliable than the equations that were evolved therefrom. In ascertaining the diameter of the pipe that will eject under the available head the needed quantity, it is found, as an almost invariable fact, that not more than 10 per cent. of the theoretical maximum is obtained in fact, or that in a pipe of uniform section, the ejecting end ejects 90 per cent. less than it would eject were the ejection to take place with the velocity $v = \sqrt{h\,2g}$, when h is considered, as it appears by actual survey. As a necessary consequence, under the older method, a pipe is selected of ten times the diameter of a circular aperture which, under the head h, would eject the required quantity were it ejecting with theoretical velocity.

Conflicting with this prevailing practice it is here recommended that *the dimensions of the supply-pipe* in its entire length *be adapted to the conditions, as set by the laws of gravitation, or to the shape that the falling body of water would assume under these laws*, under which laws the same quantity that is finally ejected must pass, and does pass, any level plane between surface of supply and level of ejection within the same

period of time, but passes such level plane or transverse section with velocities that are at no two levels the same, but which are constantly increasing as the fall continues, unless constrained by confining walls to do otherwise, and which sections must, in free fall, decrease in ascertainable proportional relation as the velocity of fall increases, to the effect that the same quantity may, within the same period, pass any point in the entire fall.

It is the object of this discussion to demonstrate the precise dimensions thus adapted, and the reasons and causes for which a new method, conflicting with prevailing practice, should be followed in planning supply-pipes.

To ensure my readers' attention, I may be permitted to preface my discussion with the statement that, under equal given conditions, a stated supply of water is secured at lower cost under the proposed new method than prevailing practice will permit, and that, for identical qualities of material, there is a large difference in favor of the new method—a difference of such magnitude that competition in the construction of pipe-lines and penstocks, made under the older system, becomes impracticable in opposition to those made in design as prescribed under the new method.

Proceeding with my discussion, I claim it to be almost impossible to intelligently discuss questions of hydraulics without using the system of interchangeable values for volume and weight, as used in the metric system. On the other hand, many good reasons can be cited for not discarding the foot- and pound-units in our American practice. The writer has made, as he inclines to think, a successful step toward adapting to the foot-pound units the system of dual values for volume and weight. As it is proposed to use these units in the present discussion, it is necessary to explain, in a few words, the nature of these new units and their adaptation to the problem under consideration.

While a column of water 1 meter long, with a base of 10 square centimeters has a volume of 1 liter, or of 0·1 cubic meter, and weighs 1 kilogram; a column of water (of identical density, of which the cubic foot weighs 62·421 pounds) 1 foot long must have, in order to weigh 1 pound, a

base of 144 square inches / 62·421 pounds = 2·306916 square inches (= 0·016 square foot).

The area of 2·306916 square inches may in consequence be used in the foot-pound system, as the area of 10 square centimeters is used in the metric system. And in consequence the fundamental equation

$$P = Q\,y\,.\,h = F\,.\,v\,.\,h = F\,.\,v\,.\,v^2/2\,g = F\,.\,v^3/2\,g$$

foot-pound, is as valid for our system of units as its equivalent is in the metric system, on condition that F be expressed in the stated proper units of 2·306916 square inches.

The expression for force may be substituted by one for work, or by the expression for horse-power-second, in reducing the value to

$$P/s = F\,.\,v^3/2\,g\,s.$$

In these and all other equations which are cited in this paper,

P stands for maximum-force in foot-pounds.

F stands for transverse section of current, ejected with force, such area being expressed in units of 144 / 62·421 = 2·306916 square inches.

F'' stands for the same area, expressed in square inches.

Q stands for cubic feet, and y for 62·421 pounds.

h stands for the distance of fall in feet, in vertical measurement between the surface of the supplied water and the level of ejection.

H stands for the head in feet above an intermediate level in a supply-pipe, situate between its upper and lower ends, being the upper part in h, of which

H° stands for the other or lower part, causing h to be $= H + H^\circ$, and H° to be the head above the level of ejection at an intermediate level between the source of supply and the level of ejection.

H'' stands for 1 foot, or for the head taken at 1 foot below the surface of the inflowing water, or for

an inlet that is 1 foot below the surface of the inflowing water.

v stands for the velocity of ejection in feet.

g stands for twice the distance of fall in the first second, assumed at the latitude of 45° for sea-level as 9·81 meters = 32·183669 feet.

s stands for 550 foot-pounds, the equivalent of 1 horse-power second.

The essential of the equation, as hereinabove expressed, is the assumption that a weight of $Q\,y$ pounds of water, falling a vertical distance = h feet, produces a force of P foot-pound, or the work of P/s horse-power second.

From the stated equation a number of values can be deduced, of which use must be made in carrying out the inquiry which is the subject-matter of this paper, and which in themselves will be of material assistance in solving all kinds of problems in hydraulics.

Such evolved values will be positive and practical values, whenever the velocity, that is one of the conditions to the value, is the velocity in fact of ejection. Such velocity, in fact, may in practice be reliably ascertained, by dividing the ejected weight of water in pounds multiplied by 2·306916, by the aperture of ejection in square inches, in accordance with $Q\,y/F = v = 2{\cdot}306916\,.\,Q\,y/F''$, when, as stated, F is the section of ejected current in units of 2·306916 square inches, and F'' the same section in square inches.

The cause for measuring head and velocity in feet, and for measuring transverse section of current and values (d and D of diameters) relating thereto, in inches, originates in our practice of designating pipes by inches of their diameters. Were it not for this custom, the value F might be expressed in units of $1/62{\cdot}421 = 0{\cdot}016$ square foot. As it is, F is more appropriately expressed in units of $144/62{\cdot}421 = 2{\cdot}306916$ square inches, both of which expressions, as such, originate in the necessity of expressing the area F in a manner that will impart to a column of water, 1 foot long, a weight of 1 pound for every unit in the expression of its transverse section = F, or in the necessity of expressing total weight of water ejected as the product of velocity of

ejection by the transverse section of ejected body (at aperture of ejection).

The values, as mentioned and obtained, by simple mathematical evolution, which must not only render service in solving my special problem, but which, as such, render useful service in many other problems in hydraulics, are as follows:

$$A\,a = \frac{148{\cdot}49}{v^3} = \frac{0{\cdot}287537832651 +}{\sqrt{h^3}} \text{ square inches}$$

is the expression for the *requirement* in square inches of transverse section of ejected current (jet, when of moderate dimensions) for producing the *force of 1 foot-pound.*

$$A\,b = \frac{81669{\cdot}5}{v^3} = \frac{158{\cdot}1516}{\sqrt{h^3}} \text{ square inches}$$

is the expression for the *requirement* in square inches of transverse section of ejected current for producing the *work of 1 horse-power second.*

By 1 foot-pound $= F \,.\, v^2/2\,g$, and by $F'' = F \,.\, 2{\cdot}306916$, and by $2\,g = 64{\cdot}367338$ feet ($g = 9{\cdot}81$ meters for sea-level and 45° lat.)

$$F'' = \frac{148{\cdot}49}{v^3}$$

and by 550 foot-pounds per second = 1 horse-power second, the stated value $A\,b$ is obtained. By $v = \sqrt{2\,g} \,.\, \sqrt{h}$ the substitute values, with h in place of v, are obtained.

$$B\,a = d = \frac{13{\cdot}75}{\sqrt{v^3}} = \frac{0{\cdot}604581}{\sqrt[4]{h^3}} \text{ inches}$$

is the expression for the *diameter required* in a circular transverse section of a jet that possesses the *force of 1 foot-pound.*

$$B\,b = d = \frac{322{\cdot}49}{\sqrt{v^3}} = \frac{14{\cdot}18}{\sqrt[4]{h^3}} \text{ inches}$$

is the expression for the *diameter required* in a circular transverse section of a jet that does the *work of 1 horse-power second.*

Because $F'' = d^2 . p / 4$, and $\sqrt{550} = 23{\cdot}473$.

$$C\,a = \frac{v^3}{148{\cdot}49} \quad \frac{\sqrt{h^3}}{0{\cdot}28754} \text{ foot-pound}$$

$$C\,b = \frac{v^3}{81669{\cdot}5} - \frac{\sqrt{h^3}}{158{\cdot}1655} \text{ horse-power second}$$

are the expressions for the *effect* of a jet that has a transverse *section of 1 square inch*, as a direct consequence of the requirement per foot-pound and horse-power, as expressed under *A a* and *A b*.

$$D\,a = \frac{v^3}{189{\cdot}0629} = \sqrt{h^3} \cdot 2{\cdot}7314671 \text{ foot-pound}$$

$$D\,b = \frac{v^3}{103984{\cdot}595} = \frac{\sqrt{h^3}}{201{\cdot}32} \text{ horse-power second}$$

are the expressions for the *effect* of a *jet* that has a circular transverse section *of 1 inch diameter*, because $C\,a \div D\,a = 1 \div p / 4$.

$$E\,a = \frac{d^2 . v^3}{189{\cdot}0649} = d^2 . \sqrt{h^3} . 2{\cdot}73 \text{ foot-pound}$$

$$E\,b = \frac{d^2 . v^3}{103984{\cdot}6} = \frac{d^2 . \sqrt{h^3}}{201{\cdot}32} \text{ horse-power}$$

are the expressions for force and work produced by any circular jet, the *diameter d* of which is known as a direct consequence of preceding values, as stated.

$$F\,a = \frac{d^2 . v^2}{189{\cdot}0649} = \frac{d^2 . h}{2{\cdot}93725} \text{ foot-pound}$$

$$F\,b = \frac{d^2 . v^2}{103984{\cdot}6} = \frac{d^2 . h}{1615{\cdot}4875} \text{ horse-power second}$$

are the expressions for force and work, produced by circular jets per foot of velocity.

There cannot be sustained any reasonable doubt concerning the fact that the *effects* thus stated and measured by actual velocity of *ejection* and by transverse section of *ejected current* (aperture of ejection) are *effects in fact*, and not effects in theory only. Such actual velocity of ejection may,

in practice, be ascertained without any other exertion than that which is connected with establishing for any case under consideration the quantity (pounds) of water ejected per second. The value F in units of 2·306916 square inches for the transverse section of current, must be determined by the aperture of ejection, and $Q\,y\,/\,F = v$ shows actual velocity of ejection. This result is not vitiated even by the ejection not taking place in a body of perfect cylindrical or other uniform section, and not by the appearance of what in hydraulics is called "the contracted vein," because the result obtained is independent of the section of the jet, except in the aperture of ejection.

But whenever the values for head or for velocity are assumed, as shown by survey of head, and as $v = \sqrt{h\,2\,g}$, in that case, the values shown are those for obtainable maximum effect ($C\,a$ to $F\,b$) or for minimum requirement ($A\,a$ to $B\,b$).

The equations $E\,a$ and $E\,b$ for *effect* of falling currents of water of circular section condition the valuation of such effects on two values, viz.: the diameter d of the aperture of ejection or of the ejected current, and the velocity of ejection. Whenever the product $d^2\,.\,v^3$ in one case is equal to such product relating to another case, then the *effect* is the same in both cases, though the two coefficients mentioned may be different singly from one another, it being evident that all variations must be inversely proportionate.

For better elucidation of the consequences that may be drawn from the stated fact, different values, relating to one another in sets, may be expressed by different symbols, such as d, v and h as one set, D, V and $H \div D'$, V' and H', etc., as other sets, it being assumed that h represents maximum head, with H, H' and H'' as minor heads.

We then have

$$E\,b = \frac{d^2\,.\,v^3}{103984{\cdot}6} = \frac{D^2\,.\,V^3}{103984{\cdot}6}$$

and in consequence

$$D = d\,.\,\sqrt{\frac{v^3}{V^3}}.$$

And in the same manner we may develop the equivalent value

$$D = \sqrt[4]{h^3 / H^3} \,.\, d.$$

These two equivalent values express the *diameter required* in a circular current ejected under a minor head H, to produce the same power as is produced under the higher head h by a current of the minor diameter d.

The result demonstrates the fact that, to produce the same power as produced under a major head h, by ejecting a current of the diameter d, the diameter D° of the current ejected under minor head H must be made larger, and must so be made at the rate of the third power of the fourth root of the quotient of the minor head in the major head, or at the rate of the third power of the square root of the quotient of the minor in the major velocity.

The following proportional relation appears as a consequence:

$$d \div D^\circ = d \div d \,.\, \frac{\sqrt[4]{h^3}}{\sqrt[4]{H^3}} = \sqrt[4]{H^3} \div \sqrt[4]{h^3} = \frac{H}{\sqrt[4]{H}} \div \frac{h}{\sqrt[4]{h}} \text{ and}$$

$$d \div D^\circ = d \div d \,.\, \frac{\sqrt{v^3}}{\sqrt{V^3}} = \sqrt{V^3} \div \sqrt{v^3} = \frac{V}{\sqrt[4]{V}} \div \frac{v}{\sqrt[4]{v}}$$

Hence:

$$D^\circ = d \,.\, \frac{\sqrt[4]{h^3}}{\sqrt[4]{H^3}} = d. \frac{\sqrt{v^3}}{\sqrt{V^3}}$$

Thereby it appears that:

I. *The requirement in diameters of currents ejected under different heads, but producing the same effect, are proportionate inversely to the velocities of ejection, divided by their fourth roots.*

This does not solve the problem before us, but emphasizes the difference between the problem of determining the diameters in the same supply-pipe at different elevations for permitting unimpeded flow, and the other problem of determining the size of ejectable currents producing the same power under different heads.

In the first specified problem sundry values are assumed as known or given, namely, the power required or obtain-

able, the quantity of ejection intended and the consequent transverse section and consequent diameter of ejectable current, as well as the main or maximum-head available or projected. The diameter d of the area F'' of final ejection is in all cases as

$$\sqrt{F} \,.\, \sqrt{4/p} = 1{\cdot}12838\ \sqrt{F},$$

and by proper development it will be found that the diameter in inches is in all cases as:

$$d = \sqrt{P/v^2} \,.\, \sqrt{2{\cdot}306916 . 2g . 4/p} = \sqrt{P/v^2} \,.\, 13{\cdot}746 \text{ inches.}$$

While in prevailing practice it is assumed that this dimension d must be increased about tenfold, in order to produce the force P, as it appears in the character of obtainable maximum effect, it is proposed in the new method that the values P and d as such be assumed as valid relatively, and the cause or necessity for increasing the value d tenfold is intended to be removed, by harmonizing the dimensions of the supply-pipe, in its entire length, to the dimensions of the body of water, as it would assume them or successively modify them, were it to fall without hindrance or resistance, or to fall in such shape as nature, by the law of gravitation, would impart to such falling body of water, of which liquid body all parts are able to arrange themselves into the forms, as result from acceleration in their falling velocities, unless *resistance* to their natural (greater lengths (v) and smaller sections ($D^2 . p/4$) arrangement will prevent them from obeying the law of nature.

In supply-pipes of uniform section throughout, such *resistance* is offered, unless their dimensions be excessive, and such *resistance retards the fall, reduces velocities or causes the effect commonly designated as loss of head, attributed to orifice of influx and to friction.*

It is the quantity, expressed in both volume and weight by $Q\,y$, which as a volume finds specific expression and description in the fundamental equations for force and work, by being there specified as an ejected column of the length v per second, and of a constant transverse section F (in units of 2·306916 square inches); and this quantity passes

any section-area per second. To remove all obstacle to the said quantity passing each section in its natural shape is the object of this research.

The assumption is, in approaching our problem, that the product $F \cdot v = Q\,y$ pounds of water per second be ejected, as a consequence of falling a distance $H = v^2/2\,g$. Nothing will be modified in this assumption by using F'', the expression for area of current-section in square inches, in place of using F, the expression of the same in units of 2·306916 square inches, because the equality between the two values is not destroyed in $2{\cdot}306916 \cdot Q\,y = F'' \cdot v$, and because all further conclusions will be based on the fact that all different expressions used in substitution for $F \cdot v$ are equal to the third value $2{\cdot}306916 \cdot Q\,y$.

The current-section F' may then be expressed as of circular form by

$$F = d^2 \cdot \frac{4}{p}$$

and the fundamental equation then reads:

$$2{\cdot}306916 \cdot Q\,y = F' \cdot v = d^2 \cdot \frac{p}{4} \cdot v = d^2 \cdot \frac{p}{4} \sqrt{H} \cdot \sqrt{2\,g}$$

The value $2{\cdot}306916 \cdot Q\,y$ is assumed as immutable, as such, but the values that are equivalent thereto, as an entirety, are assumed to be products, the factors in which may be modified inversely to one another, leaving, nevertheless, the product unaltered. The factors that are subject to such modification are v, H and d. It will be necessary to so designate these factors that each set of them, which, though singly different from one another, are conditional to the same product, give evidence in their expression that they belong to one another, and form a set in distinction of other sets. I therefore use v, h and d,—V, H and D,—V'', H' and D', and V'', H'' and D'' as such sets. And we may set down, as our fundamental condition, that an *equal quantity* (weight and volume) *pass* successively over distances of fall: h, H, H' and H'' with different velocities v, V, V' and V'', by reason of which variable velocity, at any given or selected point in such fall, the values d, D, D' and

D'' must also be modified. And it is our problem to establish a law under which this modification takes place. The same line of surface or the level of the surface of the water supplying the pipe-line is assumed as in common to the different heads, or to the values h, H, H' and H''.

H'' signifies 1 foot, and in consequence relates to a point in the course of the falling water, situate 1 foot below the surface of the inflowing water, a point which may be assumed as the orifice of influx of a pipe-line, though orifices at greater distances below the surface will also receive proper attention.

h signifies the vertical distance of fall from the surface to the level of final ejection, with a velocity v from a circular aperture of a diameter d. And H and H' relate to intermediate levels, that of H being nearer to the level of final ejection than that of H', or $h > H > H' > H''$.

The conditions, as assumed, may then be expressed by the equations

$$\frac{2{\cdot}306916\ Q\ y}{\sqrt{2g}\cdot p/4} = d^2\cdot\sqrt{h} = D^2\cdot\sqrt{H} = D'^2\cdot\sqrt{H'} = D''^2\cdot\sqrt{H''}$$

As a consequence we have, relating to different levels in the supply-pipe, the heads above which different levels are the known values H'', H', H and h, in the order of successive fall, the following resulting equations:

$$d^2 = D^2\cdot\sqrt{\frac{H}{h}} = D'^2\cdot\sqrt{\frac{H'}{h}} = D''^2\cdot\sqrt{\frac{H''}{h}} \text{ and}$$

$$d = D\cdot\sqrt[4]{\frac{H}{h}} = D'\cdot\sqrt[4]{\frac{H'}{h}} = D''\cdot\sqrt[4]{\frac{H''}{h}} \text{ and}$$

$$D = d\cdot\sqrt[4]{\frac{h}{H}}$$

$$D' = d\cdot\sqrt[4]{\frac{h}{H'}}$$

$$D'' = d\cdot\sqrt[4]{\frac{h}{H''}}$$

As the value of H'' is specifically known as $H'' = 1$ foot, and as relating to an orifice of influx 1 foot below the surface of the supply water, the diameter D'' of such orifice must be by

$$\sqrt[4]{H''} = \sqrt[4]{1} = 1 \text{ as}$$

$$D'' = d \cdot \frac{\sqrt[4]{h}}{1} = d \cdot \sqrt[4]{h}$$

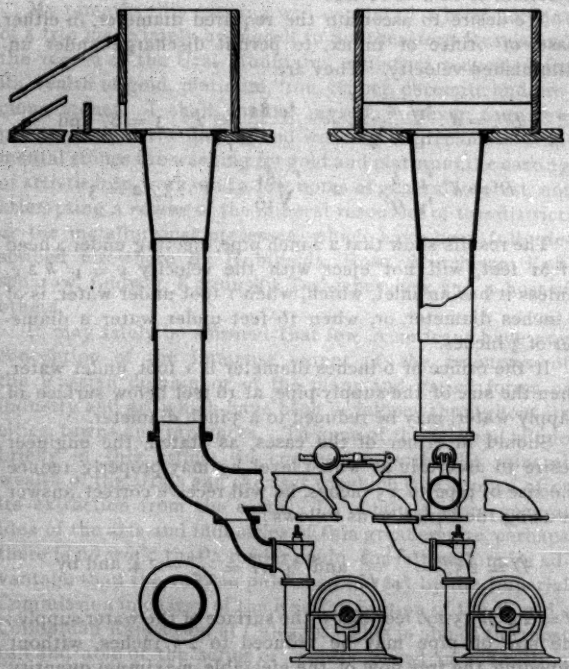


FIG. 1.

Assuming any other vertical distance $= H'$ between the surface of the supply water and the inlet of the supply-pipe, the required diameter of such lower inlet must be as

$$D' = \frac{\sqrt[4]{h}}{\sqrt[4]{H'}} \cdot d$$

Illustration: Assuming final ejection to take place from a 2-inch pipe-end or nozzle, and the head of water, above the orifice, to be in one case $H'' = 1$ foot, and in another case $H' = 16$ feet, and in both cases the head, above the level of ejection, to be $h = 81$ feet—

We desire to ascertain the required diameter, in either case, of orifice of influx, to permit discharge under undiminished velocity. They are

$$D'' = d \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H''}} = 2'' \cdot \frac{\sqrt[4]{81}}{1} = 2'' \cdot 3 = 6'' \text{ and}$$

$$D' = d \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H'}} = 2'' \cdot \sqrt[4]{\frac{81}{16}} = 2'' \cdot 3/2 = 3''$$

The results show that a 2-inch pipe, ejecting under a head of 81 feet, will not eject with the velocity $v = \sqrt{h\,2\,g}$, unless it has an inlet, which, when 1 foot under water, is of 6 inches diameter, or, when 16 feet under water, a diameter of 3 inches.

If the orifice of 6 inches diameter is 1 foot under water, then the size of the supply-pipe, at 16 feet below surface of supply water, may be reduced to a 3-inch diameter.

Should in either of the cases, as stated, the engineer desire to ascertain at which level he may properly reduce the size of pipe to 2·5 inches, he will receive correct answer in using the equation as follows:

$$D = 2{\cdot}5'' = \frac{2'' \cdot 3}{\sqrt[4]{H}} \text{ and } \sqrt[4]{H} = \frac{6}{2{\cdot}5} = 2{\cdot}4, \text{ and by}$$

$H = 2{\cdot}4^4 = 55{\cdot}296$ feet below the surface of the water-supply: the size of pipe may be reduced to 2·5 inches, without impeding the free flow of the ejectable maximum quantity of water.

(*To be Concluded.*)

THE FRANKLIN INSTITUTE.

[COPYRIGHTED.]

A TRIP TO RUSSIA AND THE URAL MOUNTAINS.*

BY GEORGE F. KUNZ.

My remarks this evening will consist of a brief account of a trip made lately by myself to Southeastern Russia and the region of the Ural Mountains, a district renowned for its wealth of gold, platinum, iron, copper, chromite and precious stones. I shall confine myself, however, to a few points, such as the finding and working of precious or ornamental stones, the washing for gold and platinum, the casting of artistic iron work, and a few notes of general interest, not attempting a *résumé* of the mineral resources of this district, or the metallurgical processes, which have been fully described elsewhere by Humboldt, Rose, Murchison, Koksharow, Ludwig, Karpinsky, Tscherneschew and a host of others.

It may safely be affirmed that few Americans have any conception of the immense extent of the resources of the Russian domain, or of the many and varied forms of industry and art which have been developed throughout its cities, towns and provinces. To some of these I shall allude briefly in this article, in connection with the mineral wealth of the Urals and the uses to which it is applied after its extraction from the earth. To obtain a more general idea of the arts and industries of this great empire, perhaps there is no work that a reader could consult with more advantage than the volume published in 1893 by the Imperial Commission in charge of the Russian Section of the World's Columbian Exposition at Chicago. This is one of the most full and able of the series of reports issued in connection with the great Fair, and though only entitled a "Catalogue of the Russian Section," it forms an octavo volume of more than 500 pages, and comprises over 1,000 titles of

* A lecture delivered before the Franklin Institute, April 20, 1898.

exhibits; while the notes in relation to a large number of them are of great value, historical, industrial and statistical.

Whoever contemplates a trip through Russia must be sure to secure a good passport. This should be *viséd* in Paris, or some European capital, before starting for Russia. From the questions put to me at these places, it soon became evident that no one of the Hebrew faith will be admitted into the realm of the Czar of all the Russias.

At the frontier the train stops for about two hours. Here, on the railroads, in the mines, on the steamers and elsewhere, I received the most courteous attention from officials and the Russians in all stations with whom I came in contact. They are exceedingly friendly to strangers.

To reach the Ural Mountains, one can go very comfortably by rail to St. Petersburg from Berlin, in thirty-two hours; or from Vienna in thirty-eight hours. From St. Petersburg the best train, leaving at eight o'clock in the evening, will take the traveler to Moscow, a distance of 366 miles, in fourteen hours, and from Moscow, 246 miles, in twelve and a half hours, to Nijni Novgorod, where, from the end of July to the middle of September, the great fair is held, at which at least $135,000,000 change hands every year in less than six weeks' time.

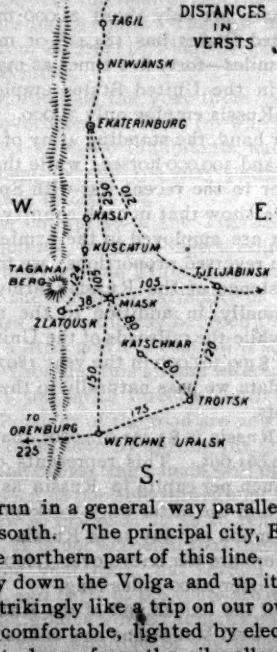
From Nijni Novgorod the traveler can usually reach the Urals by way of the various daily lines of steamboats that ply on the Volga and the Kama, 894 miles to Perm—a city of 30,000 inhabitants—in three and a half to four days. But in the time of low water in summer a week or more is frequently required.

From Perm one can go by the Ural Railroad, through the heart of the Ural to Tumen, the frontier of Siberia, a distance of 463 miles, in thirty-two hours.

Another route may be taken, however, in the dry season or winter, when the traveler can go direct from Moscow, by rail, to Zlatoust, a distance of 1,059 miles, in seventy-nine hours.

It will thus be seen that one may enter and cross the Urals by two routes, the northern one from Perm and the southern one by Orenburg. These two cities lie some dis-

tance west of the mountains, Perm in about latitude 58° north, or approximately on the parallel of the Hebrides, while Orenburg is in latitude 52°, corresponding nearly to that of London. The rich mining region of the Urals lies chiefly on the eastern or Asiatic side, between these two latitudes, at which the range is traversed by railroad routes; and the principal points to which I shall have occasion to refer lie along this eastern flank of the mountains, connected



by roads that run in a general way parallel to the range, *i. e.*, north and south. The principal city, Ekaterinburg, is well toward the northern part of this line.

The journey down the Volga and up its great affluent the Kama, is strikingly like a trip on our own Mississippi; the boats are comfortable, lighted by electricity, and the fuel used is petroleum, from the oil wells of Baku, on the Caspian Sea. If the traveler goes by way of Zlatoust, the

journey from there to Ekaterinburg, 171 miles northward, can be made by tarantas, in from twenty-four to thirty-six hours.

Russia has a population of about 110,000,000, of which the Ural region contains about 5,000,000; and the largest city in the Urals (Ekaterinburg) has 34,000 inhabitants.

The area of entire Russia is somewhat over 22,000,000 square kilometers, which is one-twenty-third that of the entire globe, or one-sixth of all its visible land; and exceeds by nearly five times the area of the United States, including Alaska.

In Russia there are only about 25,000 miles of railroad, while the United States has 184,428, or more than seven times as many miles—forty-five times as many for the area. The railroads in the United States employ 823,000 men, while those of Russia employ only 35,000.

On the other hand, the standing army of Russia consists of 835,780 men and 390,000 horses; while that of the United States had, prior to the recent war with Spain, 27,390 men.

These figures show that in each country about an equal number of men are employed in the armies and railroads together, but in reversed proportions; we may further note that the subsistence of the Russian army costs at least $50,000,000 annually, in addition to the armaments and fortifications; while the railroads of the United States made net earnings of $369,565,000 in the year 1897.

From these data we pass naturally to the next item, that of national debts.

The debt of Russia is $3,491,074,000; that of the United States is $1,700,961,695. This represents over one and a half times as much per capita in Russia as in the United States; although in the latter wage-workers earn from three to five times as much per day as in Russia.

In Russia there are ten rivers over 1,000 miles long, and five of these are over 2,000 miles long.

The valleys of the Irtisch and of the Kama Rivers, with the chain of the Ural Mountains as a connecting link, have been from time immemorial the natural route open to the Asiatic migrations, whose starting point was to the east of

Lake Baikal, and which gradually spread more and more widely on their way toward the Baltic Sea. Thus it is not surprising that the soil of these regions contains hidden archæological treasures in greater abundance than any of the central provinces of European Russia. To these we will refer later.

The river courses of Russia have done much to assist in the great migrations, and naturally guided or diverted them.

At Ekaterinburg, the heart of the Urals, starts the Great Siberian Street—the road to Siberia—one of the finest broad avenues in the world. The new Siberian railroad is to go direct from Zlatoust to Vladivostok on the Pacific, a distance of 4,000 miles.

As it is now, for half the year there is no connection between the Government of Perm (to which Ekaterinburg belongs), with its 2,500,000 inhabitants, and Moscow or St. Petersburg, except by the 170-mile journey by tarantas from Ekaterinburg to Zlatoust.

This gigantic enterprise of the Trans-Siberian railway will, when completed, be the longest railroad line in the world. It extends from the Urals somewhat south of east, passing around the southern extremity of the great Lake Baikal, which lies about midway between the Urals and the Pacific; thence a little north of east till it strikes the valley of the Amoor. Crossing this stream after some distance, it turns for about 300 miles directly south to the port of Vladivostok. Portions of the road are now under construction, especially those that by uniting the great river routes of Siberia and the connecting canals, will open partial communication as soon as possible throughout the great interior, which is now so inaccessible as to render its products of little value. It is not expected that the road will be finished before the year 1904; but several thousand miles are already laid, and parts of the route are in operation. At present, although gold is worked at many points throughout Siberia, yet the vast resources of the country in products no less valuable for use, but too bulky for easy transportation, such as coal, iron and the like, are unavailable. As

soon as the Trans-Siberian railroad is completed, these resources will be opened to the world, and also a vast amount of agricultural products which the country is capable of producing, but which are now unable to reach a market. The same is true of the stock-raising capacities of many parts of Siberia, and of the immense fishing industry that exists around Lake Baikal. On the shores of this great mid-Asiatic lake are no less than 400 fishing stations, giving employment to some 30,000 men.

As a consequence of the absence of railroads, the fact is noticeable that in all Russia the roads are generally good, and the facilities for wagon traveling are better than exist anywhere in the United States.

The traveling is all done, when not on the railroad or boat, by tarantas, especially on the government post roads. This vehicle, drawn by three running horses, is very comfortable, and one can average at least six to eight miles an hour, including the time required in the changes, which are made every twelve to eighteen miles, frequently going over ten miles an hour on the road. If the traveler contemplates a trip of some distance, or requires a long time, a good way is to buy a vehicle, put his baggage into it, and hire horses at the government post or other stations as he travels.

The Ural Mountains form the geographical dividing line between Europe and Asia. The average altitude of the entire chain is not over 2,000 feet; an elevation of 4,000 feet is exceedingly rare, and the highest peak (near Miask) in the entire range is 5,540 feet.

The chain runs north almost in a direct line from its southern point near the Aral Sea, in latitude 46 north to latitude 65 north, then deflects to the east as far as north latitude 67, and runs to the Arctic Ocean.

The average width of the range is scarcely forty miles—only in rare instances does it attain a width of 100 miles. The entire range is embraced in the Governments of Tobolsk, Perm and Orenburg.

The various inhabitants of the Ural district are as follows: In the northern part, in the Government of Perm, with 2,700,000 inhabitants, are what are called the Great

Russians; south of this, in the Government of Orenburg, with a population of 1,300,000, there is a tract of land inhabited by the Bashkirs, a Mohammedan sect, who live in villages, and are an industrious, peaceful people. South of and bordering on these, for the purpose of keeping peace between the other peoples just named, and also for maintaining the power of the Czars, are the famous Cossacks, who separate the Bashkirs from the Khirges, and interspersed through here are also Tartars.

The Khirges are a rude, nomadic people, who raise immense herds of cattle, sheep and horses, which they sell or trade to the inhabitants of Perm, Orenburg and the Volga district.

There has just appeared a work of great value relating to the geology and mineralogy of the Ural region, viz.: the collection of guide-books prepared by the Russian committee for the series of scientific excursions in connection with the seventh meeting of the International Geological Congress, which was held during the past summer in St. Petersburg.* This volume consists of thirty-four monographs by leading Russian geologists, treating of the different portions of country to be visited or traversed by these excursion parties. These papers are accompanied by maps, illustrations, bibliographies, etc., and have been prepared with the utmost care and pains, and strictly brought up to date in their accounts. Five of these monographs relate to the mining region of the Eastern Urals—the same that was visited by the present writer.

This remarkable and indeed monumental work is one that reflects great honor upon the geologists who prepared its various parts, and it shows very strikingly the liberal and princely manner in which the Government and the scientific men of Russia plan and carry out such courtesies. The whole forms an octavo of over 500 pages, beautifully printed, and bound in a spring cover, so that each local

* Guide des Excursions du VII Congress Géologique International, avec 39 planches, nombreuses figures, cartes locales et une carte géologique de la Russie d'Europe a l'echelle de 1:300,000. St. Petersburg: 1897. Imprimerie de M. Stassulewitsch, Wassili Ostrow 5, ligne 28.

monograph could be taken out and used separately during the portion of the journey with which it is concerned. The translation, chiefly into French and in some cases into German, is excellent; and the whole is a noble gift to the geologists from other lands who attended the Congress.

These excursions, which were planned to visit all the districts of Russia most interesting to the mineralogist and geologist, were arranged on a scale truly imperial in liberality. By special order of the Czar, all the members who took part were provided with first-class transportation, free of expense, over the railroad and steamer routes selected, to points as distant as the Eastern Urals, the Caucasus, the Crimea, the oil deposits of the Black and Caspian Seas, etc. An example of the faithfulness with which this pledge was carried out, may be cited in the following instance: It was found at a late date in the arrangements, that there were no first-class cars on the road between Tiflis and Batoum on the Black Sea, over which one of the parties was to travel; and the Government immediately sent five cars to that remote section, at a cost of $600 each, solely for the use of the excursion.

In speaking of the mines of the Ural Mountains, it is well to observe that this term is employed in a very general sense, somewhat as the name Alleghany is with us. The Urals, in fact, comprise several ranges, of which the easternmost is the one specially referred to here. This eastern range is frequently designated as the Ilmen Mountains, though, in fact, this term is rather too limited. The richest mining districts are indeed in the Ilmen Mountains; but the same line of elevations, geologically and geographically, continues, with some interruptions and under various local names, for a long way parallel to the main Urals at a distance of from twenty to forty miles east. In a general way, therefore, it holds somewhat the same relation to the Urals proper, as the Blue Ridge does to the main line of the Alleghanies, and in the same manner bears different names in different parts of its course.

The principal rocks of the Ural region are metamorphic-

chloritic and talcose schists, serpentine, quartzite, coarse granite, gneiss, limestone and dolomite.

The mineral statistics for 1892 show that, as compared with Russia, the United States produces ten times the pig-iron, twenty-three times as much coal, twenty-three times as much copper, fifty times as much silver, six times as much quicksilver, 200 times as much lead and five-sevenths as much petroleum; whereas Russia produces nearly all the platinum and three times as much manganese; also, three-fourths as much gold.

A brief history of the origin of the greatest mining estate in the Urals, Nijni Tagilsk, may prove interesting.

When Peter the Great visited Tula in 1710, he brought with him a revolver which had been presented to him by an English nobleman.

This having gotten out of order, he inquired of the Governor of Tula if he had any one among his many skilled metal workers—for which the Government of Tula has always been noted—who could repair it.

The Governor immediately replied that one Demidoff, a young smith, undoubtedly possessed the requisite skill. Demidoff was then called, and assured the Emperor that he could put the revolver in perfect order. Peter the Great left it with him, and came again in about ten months. Demidoff handed him a revolver, which he, the Czar, examined carefully and seemed pleased with it, and complimented him on the good repair. He then showed him another one which was not quite as good; but this was the original one, he having made a new weapon better than the old. His expertness pleased the Czar, who then gave him and his heirs Nijni Tagilsk as long as it should be used as a mining estate.

Demidoff struck roads through an impenetrable forest, so true in direction and location, that all attempts to make better lines have failed, and his original roads are used to this day.

So expert was Demidoff as a smith that it is commonly said that he was able to put hoofs on, and had harnessed, a pair of fleas.

The celebrated mining locality of Nijni Tagilsk com-

prises really several separate mines. There are in the first place, six important mines of magnetic iron ore, which surround and penetrate the famous iron mountain, known as Mount Wyssokaia (or in Russian, Wissokaiagora), a somewhat isolated hill of porphyry 2,000 feet long, 1,500 feet wide, and 250 feet high. Of these mines, Nijni Tagilsk is the first and the most noted, the six together dividing up the approximately circular hill in something like irregular sectors. The ore taken out is used in the great iron works of the adjacent town of Tagil, which were founded by the original head of the Demidoff family, just now referred to. A little distance southward, close to the base of the mountain, is the celebrated copper mine of Mednoroudiansk, from which nearly all the malachite used in the world has come, a circumstance that has made this locality famous. It is unfortunate that the name Nijni Tagilsk, which really belongs to the adjacent iron mine, should have become so identified with the malachite, in mineralogical books and collections, that the error can probably never be corrected. The occurrence of the ores is peculiar and interesting; the iron is in beds and seams closely involved among the porphyritic rocks, in such a manner that Professor Tschernitschew, the eminent authority who has described these mines for the recent Congress of Geologists, regards them as of simultaneous formation with the igneous rocks in which they occur. The copper mine forms an ellipse 1,800 feet long and 290 feet broad, and the ores occur in ferruginous clay, apparently formed by an alteration of beds of tufa or breccia derived from the porphyries and other adjacent rocks, and included between upturned beds of Devonian limestone.

In 1835, an enormous mass of malachite was struck in mining at Nijni Tagilsk, at a depth of over 200 feet, and beneath the bed of a small stream, known as the Roudianka. This great mass or block, when disengaged from the surrounding rock, measured some 17 feet by 8, with a thickness sloping from about 6 feet at one end to a little over 1 foot at the other. Its total weight, including portions cut off in extricating it, was estimated at 65,000 kilograms. The block was surrounded and partly penetrated

by iron and manganese ores; but large portions of it were compact malachite, of reniform structure, beautifully varied with light and dark green. The inflow of water rendered it difficult to determine what lay below the mass; but it was thought that perhaps this was only the upper portion of a more extensive body of malachite. The largest mass previously found was in the Gournichef mine, and weighed 1,789 kilograms.

The copper deposit at this locality is attached to the magnetic iron mountain Labaschka, which is 3,000 feet long, 1,000 feet wide and 100 feet high. The Wissokaiagora is covered to a depth of 30 feet with loam—the upper layer is reniform limonite, then other forms of limonite, coarsely and finely granular, gradually changing into a compact magnetite, flanked on one side with compact crystalline limestone, containing silurian fossils, notably *pentamerus*, and on the other side with diabase.

The magnetite of the Labaschka is so highly magnetic, that all the tools brought in contact with it change to magnets. No ore poorer than 60 per cent. of iron is ever used, or any that is at all impure. From this ore is made the famous Russian sheet-iron, and there is enough in sight here for a hundred years to come.

A little farther to the northeast of Wyssokaia is another and loftier hill, belonging to the Government, known as Mount Blagodat. Here again occur extensive mines of magnetic iron, associated in the same intimate manner with masses of porphyritic rock, which have been forced out among limestones of Lower Devonian age.

*On the entire estate of Nijni Tagilsk (30,000 inhabitants) and Neviansk Savod (16,000) there is not a single mile of railroad. Everything is hauled by horses; and when one inquires why, he is informed that the mines were granted to the original Demidoff, on the condition that he should employ every person in the entire domain. Hence the

* I must also express my sincere thanks to Prince Demidoff, who, in response to the letters that I had to him, arranged that his engineers, Grammatakoff and Hamilton, not only afforded me every opportunity, but the horses and men to guide me over this marvelous and unique estate.

caravans, which consist of from five to forty wagons in summer, or sleds in winter, are constantly seen crawling along the roads to the railroads. Strange to say, a rigid eight-hour law exists in the Urals. No one is allowed to employ a man more than eight hours for a day's labor. It is customary for them to begin work at six in the morning and to stop at six in the evening. One hour is allowed for breakfast, from eight to nine; two hours for dinner, from twelve to two, and one hour for supper, from four to five.

The results accomplished with primitive appliances are in striking contrast to the modern methods used in the United States, notably in Minnesota, where in one day 4,000 tons of ore are raised by one steam-shovel, railroaded to lake docks and sold over 1,100 miles distant at a profit of $2.85 a ton.

An interesting social custom at Nijni Tagilsk is, that many of the people use visiting cards, made at the Demidoff works, out of Russian sheet-iron; this rolled to the thinness of paper, is even more flexible than a thin plate of mica.

The auriferous deposits of the Urals are, as usual, of two kinds, which have been called by Karpinsky primary and secondary. In the former, gold is found either in quartzose vein-stuff, or interspersed through the mass of crystalline rocks, such as diorite and serpentine; while the secondary deposits are auriferous sands, either immediately overlying the primitive deposits, or transported and rearranged at some distance from the point of origin.

The primary gold deposits of the Urals are very numerous, four groups of them being actually worked, namely, those of Berezowsk and Gora Blagodat, those of the district of Miask, those of the Bashkir territory and in that of the Orenburg Cossacks.

The Berezowsk deposits, which are the only ones that have been systematically developed to any extent, are included in an area of about twenty-two square miles, in which the prevailing rocks are schists penetrated by numerous veins or dykes of a fine-grained granitic rock containing pyrites and known as beresite, which vary in thickness from

3 meters to 40 and upward, and in many cases extend beyond the limits of the mining region. These beresite dykes are traversed by numerous fissures filled with quartz, forming veins varying in thickness from about 10 to 70 millimeters, or on an average 30 millimeters, having a general east and west course, often uniting into groups, but never becoming parallel to the enclosing dyke. Sometimes, but rarely, they pass from the beresite into the neighboring schistose rocks. The vein-stuff as well as the rock, where most auriferous, is rusted from the decomposition of the pyrites. The best mines yield from 1 to 1½ ounces per ton, 10 grams (about 7 pennyweights) being considered the lowest workable limit. The pyrite is often much richer than the quartz, in some instances averaging up to 6 or 7 ounces per ton. Below the level of decomposition of the pyrites into gossan, or, as they are locally called, krassiks, the gold appears to be entirely contained in the sulphides.

The secondary auriferous deposits, although called sands, are almost entirely clays, pure or somewhat sandy, and enclosing rolled masses and blocks of many different rocks. They are found throughout the whole Ural region, over a length of more than 500 miles, filling the valleys and forming marshy plains on both slopes of the chain, the larger development, however, being on the eastern side. They form placers of elongated shape, closely conforming to the course of the valleys and ravines in which they occur, and evidently but little removed from the rocks whence they have been derived. In many cases they have not been transported at all, but are merely the decomposed and washed surface portion of auriferous veins beneath; and the gold-bearing sands can be traced almost directly downward into crumbling gold quartz. At other times they have been transported somewhat, and the gold is richest in a band or line which seems to mark the course of the strongest part of the current. Where there are outcrops crossing the bed, or where the surface (as usually when it is limestone) is irregularly worn or fissured, there the gold accumulates as by a natural riffling process, and the beds are exceptionally rich. From this circumstance has arisen an

idea that the placers are richest where the rock is limestone; but this is only accidental, and the actual richness depends mainly upon the immediate proximity of the greenstone and talcose and chloritic schists in which the veins occur.

The placer deposits are believed to be very local, and geologically very late; they are all post-tertiary, some of them even recent. The older ones contain remains of quaternary animals, such as rhinoceros and mammoth, the later ones in some cases have yielded objects of human handiwork.

The auriferous beds or placers vary in thickness from about 1½ to 3½ feet, in breadth from 60 or 150 feet, and exceptionally 300 feet, and in length from 60 or 80 feet to 1,500, the direction being generally parallel to that of the chain. The most extensive deposits are those of Balbuk, 2¾ miles long, and Stolbuk, 3¾ miles. The sterile covering or overlying layer is usually less than 13 feet thick, although exceptional deposits have been found at 60 and even 130 feet below the surface. The overlying mass very frequently contains peat bogs. The amount of gold found varies from 12 to 39 grains per ton of sand, although occasionally it is double or even four times the latter amount.

The gold varies much in size, as usually in such deposits. The largest nugget obtained, from the Tzarévo-Alexandrovsky placer, near Miask, weighed 36 kilograms.

In the Kotchkar district placer mining dates from 1844, on the small rivers known as the Kaminka and Sanarka. These beds yielded also valuable gems, topaz, beryl, amethyst, euclase, ruby, etc., and became celebrated therefor. After some twenty years or more the yield of gold began to diminish, and vein mining was taken up. This has now become the principal method of exploitation since about 1868, and the placers are quite subordinate. The annual yield in the Kotchkar district is now about 1,600 to 1,800 kilograms of gold, of which the vein-working furnishes 1,300 to 1,400. The total production in the district since 1844 to the present year is stated to be about 47,000 kilograms, of which 25,000 have come from the placers and 22,000 from the rock.

Not only in the region just mentioned, but widely throughout the Urals, many minerals are found with the gold in these alluvial deposits, especially magnetic iron sand, with ilmenite and chromite, much garnet, also zircon, beryl and other gems, occasionally diamonds, though none of any consequence, and platinum, of great importance. Diamonds are also found in gold placers on the west side of the Urals, in the valley of the Poloudenka River and its tributary, the Adolphe, at a point somewhat north of the Ural railroad, some 240 miles east of the city of Perm.

The platinum of the Urals is nearly all found on the eastern side of the range. It has not yet been obtained commercially except in alluvial deposits, in which it is always associated with gold. Sometimes the latter predominates, and the platinum may not exceed 1 per cent. of the product of gold; while, on the other hand, gold may be almost absent; and the deposits in which this condition prevails, although less abundant, are those of most value.

These are confined to the districts of Nijni Tagilsk, Gora Blagodat and Biseik. The first of these localities extends for about twenty-five miles to the south of the village; and judging from the associated minerals, such as olivine and chromite, the deposits appear to be derived from the débris of a mass of serpentine known as Mount Solvaiska or the White Mountain. The platinum is found in grains and nuggets; the largest of the latter known, weighing about 320 ounces, is in the Imperial Museum at Vienna. The yield varies from 39 to 195 grains per ton. The richest deposits, those of the Martian River, are from 13 to 16 feet thick, and are covered by 60 to 70 feet of overlying material, chiefly clay. The conditions of occurrence in the other localities are similar, except at Gora Blagodat, where the bed-rock of the alluvium is limestone, but outcrops of porphyry and serpentine are found in the vicinity.

In the platinum sands and gravels are occasionally found masses of the metal associated with and occurring in chromite; and as in the platinum gravels serpentine is always found associated with an abundance of chromite, it seems

evident that the source of the platinum must be in serpentine, originally a peridotite.

The first discovery of this metal in the Urals was made in 1824, and from that time till now, the richest yield has been along the valleys of the Martian and Tchaouch Rivers, and of the River Isa, in the neighboring district of Nijni Tourinsk. Thus far it has only been mined from the placers, but the theoretical conclusion previously referred to, that its source is really in the serpentine rocks, which had come to be generally adopted of late by the Russian geologists, has now been fully established. The first actual discovery of platinum in the rock was made accidentally in 1892, by a workman, in the Martian River district. The locality was subsequently examined and reported upon by Professor Inostranzew, with full confirmation of the occurrence of platinum *in situ* in the serpentine.

This rock, however, is itself a secondary one, resulting from the alteration of others, usually of the massive eruptive rock, termed peridotite, which occurs largely in this eastern part of the Ural system. Professor Tschernitschew, in a recent memoir on the region, traces all the serpentines of the Urals to the alteration of peridotites and diallage rocks, and holds that this process was accompanied with the separation of the chromic-iron, which plays so important a part in many of the serpentines, both there and elsewhere, and with the precipitation throughout the rock of both platinum and gold.

The gold deposits are partly the property of the crown or its lessees, and partly of private individuals; but in the latter case there is often a reservation of minerals which are subjected to royal rents. The rate paid by the crown lessees is from 8½ to 20 per cent., in addition to which a 3 per cent. tax is levied on all gold produced in any of the mines, the entire output being compulsorily salable to the Government.

The whole gold product of the Urals and Siberia is sent to the imperial assay office at Ekaterinburg, where it is melted and cast into bars, the assay of which forms the basis of final settlement between the Government and the miners.

Platinum working, on the contrary, is free from all taxation, and as the Government monopoly of refining, which was kept up for a time, has been abandoned, the product is mostly placed on the London and Paris markets, and there controlled by one or two individuals.

In working the alluvial gold deposits, two methods are followed. In the first, the plant and apparatus are provided by the ground-owner, who hires labor and directs the operations either personally or by deputy; while in the second, a system of tribute is followed, the ground being let to free laborers or starateli, who provide everything necessary for working, and deliver the product at a fixed rate to the proprietor. This price may vary, according to the difficulty of working, from $9 to $10.50 per ounce; but in all cases the prime cost in the proprietary workings is higher than in those of the free laborers, who are able to handle, with a profit, material with but from 8 to 10 grains of gold per ton. Platinum sands are considered poor when containing less than 45 grains of the metal per ton, and rich when above 180 grains. The lowest profitable limit seems to be about 39 grains.

*The platinum workings of Avorinski are at present the most important of that class. The deposits, from 13 to 16 feet thick, lie upon a conglomerate of serpentine, and are covered by nearly 80 feet of barren material; they extend for about one-and-a-half miles, with a breadth varying from 70 to 250 feet.

At Avorinski the average yield is about 87 grains of platinum minerals per ton; but in places it goes up to twenty, thirty or even fifty times as much. The working is entirely subterranean, but open, small pits 70 to 80 feet apart being sunk to the deposit, and the material, drawn to the surface by windlasses, is washed in the ordinary Siberian frame at the mouth of the pit. About 400 hands are employed, the work going on night and day.

The crude platinum contains about 1 part in 4,000 of

*The illustrations taken at the time by the author are reproduced in the volume on Mining, 11th U. S. Census, 1890.

gold, which is separated by amalgamation and washing with water in large capsules. The final product contains 90 per cent. of platinum.

Besides the platinum found from Gora Blagodat, not far from the Isa River, to Nijni Tagilsk, a distance of over fifty miles, it occurs also near Miask, more than 100 miles further south. But here, only about 1,200 ounces are obtained annually, while the yield of the entire Urals is about 55,000 ounces.

The platinum district of Isa River and its tributaries is worked by the Government, and by a number of private owners jointly with the Government. The platinum is whiter than that of any other district; whereas that from the Demidoff estate in the Martian Range, farther south, has always a rusty appearance.

PRICES PAID FOR PLATINUM WIRE.

	Per Ounce.
1883	$7 35
1884	7 80
1885	7 75
1886	
1887	7 80
1888	7 65
1889	8 50
1890	12 95
August, 1890	17 00
December, 1890	17 00
January, 1891	16 85
February and March, 1891	14 00
April and May, 1891	13 00
June, 1891	12 00
August, 1891	12 50
September, 1891	11 00
October, 1891	10 20
November, 1891	9 80
December, 1891	9 40
December, 1894	11 00
May, 1895	10 40
May, 1896	12 40
May, 1897	14 00
July, 1898	14 40

Leaving now the mining of the precious metals, we turn to the iron industry of the Urals, which presents some feat-

ures of special interest. We have already noted the smallness of the iron product of Russia as compared with that of our own country; and the reason of it, also, as largely due to lack of transportation facilities. But the Russian iron-work has great importance notwithstanding, and is well deserving of attention.

At Zlatoust, formerly the terminus of the Orenburg Railroad, in the very heart of the Urals, there is a Government armory, where many of the firearms, swords and other weapons used in the Russian army are made. In addition to the arms, some remarkable specimens of cisselier or chisel work, repoussé work and etching of iron and steel are executed here in great perfection, principally in the ornamentation of table knives, daggers, swords and quaint oriental weapons. This etching and ornamenting of iron-work is also done by a number of local masters throughout the district. Some remarkable examples were presented to Sir Roderick Murchison, and are on exhibition now in the Royal School of Mines in London.

From these armory works at Zlatoust there was sent to the Columbian Exposition at Chicago a remarkable display of iron and steel products, comprising over 150 articles illustrating the skill and taste of the Russian ironworkers. Among these were weapons of all kinds—swords, sabres, hunting knives, etc.—some forged, others cast, many damasked, all elegantly ornamented and mounted; then a series of table knives and fruit knives, the blades decorated with designs in blue or gold, fruit knives gilded, nickel-plated, etc., the handles of wild-goat's-horn, ivory, ebony, malachite, jasper, all elaborately wrought and ornamented, and a number of miscellaneous articles of *vertu*, all designed and manufactured at this remote spot, the very name of which is scarcely known to most of our people.

At Kasli, 130 versts south of Ekaterinburg, and about the same distance north of Zlatoust, are situated the Kasli Iron Works, remarkable for their fine artistic castings.

It may be of interest to mention that these Kasli Iron Works daily cast kettles, or gypsy or caravan cook pots, to the extent of 32,400 pounds. These are of remarkable thin-

ness, weighing less than 30 pounds each, although more than 3 feet in diameter. They also make lavabos, or laving dishes, used by the Mohammedans in their religious ablutions, which they are supposed to perform every day. These are hauled by horses to Troitzk, about 150 miles, where they are purchased by the Khirghes, Persians, Turkomans, natives of Siberia and other oriental countries, who carry them away on camels, and who use up the product of these works, amounting to 550 tons a year.

The engineer, Karpinsky, whom I had the pleasure of meeting after visiting the works, had the courtesy and generosity to present our United States National Museum with a large series of these articles.

At Troitzk, in Orenburg, in the steppes east of the Urals, a great fair is held every May, when thousands of camels are brought to that city (which is the beginning of the Orient in every sense of the word) bringing Eastern products and returning loaded with these pots. Camels with one hump carry two loads of ten poods each—720 pounds. These camels sell as high as $125, whereas a camel with two humps, which is only able to carry one load of ten poods—360 pounds—sells for only $60 to $75.

An important economic mineral of this region is chrysotile, a fibrous serpentine, often called asbestos, and sold as such. It is extensively worked near Baschenova, twenty miles off the Siberian road, near the old emerald mines. Over 1,000 men and women are employed here, who generally come some distance from the surrounding country, and must obtain leave of absence from the chief of police of their district—their papers requiring a number of revisions during a year—as unrestricted migration is not permitted in Russia. The working is all done by stripping the serpentine in layers of 4 to 5 feet deep.

While visiting the Petrokamenski Savod, Government of Perm, my attention was called to a new discovery of chrysotile on the Wuoluij River, seven or eight miles west of Petrokamenski Savod, which is likely to be of great importance. It is found loose in the soil, as well as attached to the serpentine. Part of the material found here consists

of masses in which the fibres are over five inches in length, of remarkable purity and strength. From the fact that this locality is at so great a distance, 120 miles, from Baschenova, there is every reason to believe that this useful industrial mineral, which is commercially used for many of the purposes of asbestos, may exist in large quantities in the Ural Mountains.

In 1891, in the Revdat district of Revdenski, a series of nickel ores occurring in serpentine was found, resembling in many respects the minerals found at Riddle, Douglas County, Ore. To one of these dubious silicates the name of Karatskoffite has been given.

Immense tracts of peat or turf exist throughout the Urals. Should the use of this become general, an opportunity would be afforded for the regrowth of the forests for which this region was so remarkable less than half a century ago. Wherever the original growth of pine has been removed, the second growth is always one of birch, the bark of which is extensively used throughout the Urals for milk-pails and other utensils. The peasants have also begun to use turf instead of wood as fuel; and the Syssersk Iron Works began to use it only a few years ago, for the smelting of iron. These turf deposits were described and their extent remarked on by Ludwig, as early as 1846.

In addition to the cutting down of the forests for fuel, may be mentioned the ravages made on these pine woods by a bombycid moth (*Bombyx piniperda*). For a distance of over three miles a little south from Vavlamova, Government of Perm, these insects have killed every pine tree on both sides of the road. Strange to say, the birch trees are not injured, but every pine has been destroyed, with the exception of a few trees that were isolated in a group of birches, suggesting that a border of birch trees would prevent the ravages of this destructive insect.

About nineteen-twentieths of all the buildings in Russia are of wood, and these are entirely destroyed by fire once in fourteen years. These fires are often very disastrous. In May, 1890, for example, a fire at Neviansk Savod destroyed 1,800 houses, and thirty-eight persons lost their lives, either

by fire or by drowning in the lake whither they were driven by the flames. In June of the same year, at Kanova, a village ten miles from Neviansk, more than fifty houses were destroyed.

In the south of Orenburg, in the Bashkir country, where trees are scarce, one can always be sure that a wood or grove marks the site of a graveyard, in which, if uninformed, one might camp for a day without knowing what it really was, as only an angular stone, from 1 to 3 feet high, is placed on the spot to mark a grave. These rocks project in all positions, and rarely, if ever, does one of them bear an inscription.

My friend, Mr. H. Templeton Ellicott, an English mining engineer, who had rendered the Bashkirs many services and won their favor, was offered the highest honor that a Bashkir can offer a Christian—the privilege of having his body interred in a Bashkir graveyard at his death. Mr. Ellicott, up to the present time, has not accepted the honor.

South of the Bashkir country and near Kushva, in a district over ten miles long, an immense amount of mining for gold is carried on, frequently in a very primitive manner, by the peasants, who either work alone or have a very small force of men digging out the alluvial gravel from a depth of 6 to 20 feet.

I was especially struck with the curious homes of these people. The entrance to some was below the surface of the ground, the roof projecting only from 2 to 4 feet above the ground, the small window running from the ground to the roof, and the steps going down inside of the house.

[*To be concluded.*]

MECHANICS OF THE CAMBERED BRAKE-BEAM.

By Irving P. Church, C.E., Ithaca, N. Y.

By "brake-beam," in this paper, will be understood the *trussed* beam shown in diagrammatic form in *Fig. 3*, consisting of a prismatic bar or beam AOB, a short post or strut, OD, and two prismatic tie-rods or tension-members, GD and $G'D$, meeting the post at the joint D. By "cambering" this brake-beam is meant forcing together the extremities B and G (and A and G') until they meet, and permanently fastening them in this position. In the assumption of this constrained form the elastic limit is not supposed to be passed in any member. This constrained or "cambered" form is shown by the full continuous lines in *Fig. 4*, in which the vertical dimensions of the whole frame, and the amount of bending of the bar AOB, are much exaggerated.

This state of initial constraint, brought about before the brake-beam is put to use, occasions a certain initial tensile force (T_0) in each of the tie-rods, and a thrust (Q_0) in the post, and subjects the bar AB to combined flexure and thrust. It is the object of this paper to determine the stresses induced in the various members of the brake-beam when employed in pressing the brake-shoes at its extremities against the car wheels; and also the deflection of the middle point, C, at the same instant.

As preliminary to the final object, it will be necessary to recall certain relations between the various quantities concerned in the case of an elastic prismatic bar of homogeneous material under combined flexure and thrust, as shown in *Fig. 1*. Let the length of the bar (originally straight) be $2l$, and let it be pressed against a single support B, at the middle, by two oblique equal forces, P and P, applied at the extremities O and O', at equal angles α with the tangent line drawn at B to the elastic curve thus produced. Let the sectional area be F square inches, the modulus of elasticity of the material E pounds per square inch, and the moment

of inertia of the cross-section I (referred to an axis containing its center of gravity and perpendicular to the plane of flexure), and Q pounds the reaction of the support.

$$\text{Evidently } Q = 2\,P\,\sin.\,a \tag{1}$$

According to the ordinary and well-known theory, the bar will be shortened by an amount

$$2\,c, \text{ where } c = \frac{(P\cos.\,a)\,l}{F\,E} \tag{2}$$

while the deflection d (see figure), unless the angle a is very small, is given by the formula

$$d = \frac{(P\,\sin.\,a)\,l^3}{3\,E\,I} \tag{3}$$

We note in the figure that the right-hand extremity of the bar has been displaced a distance c longitudinally, and a distance d laterally, from its original position A. A similar statement, holds, of course, for the other extremity.

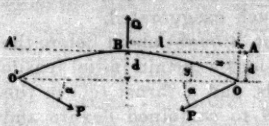


FIG. 1.

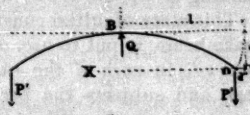


FIG. 2.

[NOTE A.—It will doubtless be of interest to mention more exact relations in connection with the bar in *Fig. 1*, for the benefit of those who would like to follow up the matter with greater theoretical accuracy.

A more exact expression for the deflection d can be obtained by treating the elastic curve $O\,B$ according to a method similar to that outlined on p. 545 of Professor Bovey's "Theory of Structures," for an obliquely loaded and bracketed column; that is, by writing the bending moment, or "moment of stress-couple," at any section $= (P\,\sin.\,a)\,x + (P\cos.\,a)\,y$, instead of $(P\,\sin.\,a)\,x$.

This leads finally to the form

$$d = (\tan.\,a)\left[\sqrt{\frac{E\,I}{P\cos.\,a}}\,.\,\tan.\left(l\sqrt{\frac{P\cos.\,a}{E\,I}}\right) - l\right] \tag{3a}$$

Incidentally, it may be remarked that if the angle α were zero, the deflection d would also be zero, *unless*

$$tan\left(l\sqrt{\frac{P}{E\,I}}\right)$$

were infinite, in which case d would be indeterminate, but

$$l\sqrt{\frac{P}{E\,I}}$$

would have to be

$$= \frac{1}{2}\pi, \text{ or } \frac{3}{2}\pi, \text{ or } \frac{5}{2}\pi, \text{ etc.}$$

In other words, we are led to Euler's formula for a slender column.

(If α were greater than 90°, we should have the case of combined flexure and tension treated on pp. 356, etc., of the writer's "Mechanics of Engineering." This case is also given by Prof. James MacMahon, in his chapter on "Hyperbolic Functions," in Merriman and Woodward's "Higher Mathematics." The result for the deflection in this latter treatment (p. 152) is very nearly the same in form as in Equation (3a) above, but contains, instead of

$$tan.\left(l\sqrt{\frac{P\ cos.\ \alpha}{E\,I}}\right)$$

the hyperbolic tangent of

$$\left(l\sqrt{\frac{P\ cos.\ (\pi - \alpha)}{E\,I}}\right)$$

where α still refers to *Fig. 1* of this paper, but is greater than 90°.)

Besides the longitudinal shortening $2\ c$. of the bar, as due to the thrust component $P\ cos.\ \alpha$, we ought more strictly to consider what might be called a "longitudinal deflection," as illustrated in *Fig. 2*, where a case of pure flexure is shown, the forces P' and P' being perpendicular to the bar. The extremity of the bar having been displaced from O' to O during the gradual increase of the force P' from a zero value, $O'B$ being tangent to the elastic curve at B, the middle of bar, we note on drawing $O'V$ perpendicu-

lar to $O'B$ that a displacement $O'V$ of the extremity has occurred in the direction of the length of the bar, and this we may call a "longitudinal deflection" of extremity, due to the curvature of BO, and not to thrust. The value of this distance $O'V$, $= d''$, can be obtained by a consideration and application of the properties of a curved beam or elastic arch, and is

$$d'' = \frac{1}{15} \cdot \frac{P^2 l^5}{E^2 I^2} \qquad (3b)$$

To avoid complexity in what follows, the stricter relations mentioned in this note will not be observed. The effect of shearing stresses in influencing deflection will also be neglected.]

To determine the initial stresses in the brake-beam, *i. e.*, those due to camber, let us consider *Fig. 3*, which shows in

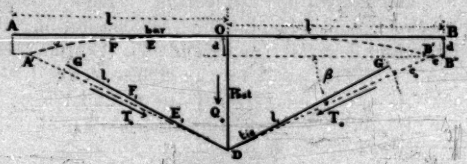


FIG. 3.

full continuous lines the bar, the post, and the two tie-rods, *under no strain*. For the bar, let the sectional area, its moment of inertia and the modulus of elasticity be denoted by F, I, and E, respectively, and the half length by l. Similarly, for each tie-rod we have F_1, E_1, and l_1 $(= D\,G)$. Conceive a circle to be struck with center at D and radius $= DG$. Denote the difference between the lengths $D\,G$ and $D\,B$ by λ; that is, λ is the amount by which each tie-rod is too short to reach the extremity of the bar without inducing stress. In the production of the camber, the post, which is short and for local reasons is often made very thick, is considered as remaining unchanged in length.

When the ends of the tie-rod and bar on the right (and simultaneously on the left) are forcibly brought together (by screwing up a nut, for instance), they will be found at

some point B'. The end B of the bar has been displaced sideways a distance d; and also displaced longitudinally a distance c, due to the thrust $T_o \cos. \beta$, T_o being the tensile force induced in the tie-rod; while the tie-rod itself becomes elongated by an amount c_o dependent on T_o. Between the quantities concerned we now have the following relations, from the principles of "Mechanics of Materials:"

$$d = \left(\frac{l^3}{3 E I}\right) T_o \sin. \beta = R\, T_o \sin. \beta \qquad (4)$$

$$c = \left(\frac{l}{F E}\right) T_o \cos. \beta \quad = N\, T_o \cos. \beta \qquad (5)$$

$$c_o = \left(\frac{l_1}{F_1 E_1}\right) T_o \qquad = N_1\, T_o \qquad (6)$$

(for brevity's sake R, N and N_1 are used instead of the factors which they are seen to replace); and also, since the sum of the projections of d, c and c_o upon the line joining B and D must equal λ,

$$c_o + c. \cos. \beta + d. \sin. \beta = \lambda \qquad (7)$$

So far as its use in the analysis of this paper is concerned, the angle between the tie-rod and the tangent-line at middle point O of the bar, is not supposed at any time to vary appreciably from a fixed value, which will be called β. Given all the quantities in these four equations except d, c, c_o and T_o, these last-named can be easily determined; or, if d is known by actual measurement, we do not need to know λ, but can determine T_o directly from equation (4).

We are now ready to consider the cambered brake-beam when subjected to external forces in service. These external forces are the pressure on its middle point, 2 W, and the two reactions, W and W, one from each brake-shoe; see *Fig. 4*, in which the vertical dimensions and the degree of distortion are much exaggerated to secure clearness in demonstration.

The continuous full lines $A\ O\ B\ D\ O$ in *Fig. 4*, represent the brake-beam in its cambered condition, with its extremities or joints A and B just touching the brake-shoes (and the latter the wheels), but as yet not under external pressures. As

the pressure 2 *W* is gradually applied (*i. e.*, increased gradually from a value of zero to a value of 2 *W*) the joints *A* and *B* experience corresponding pressures increasing to a final value of *W* at each joint. The dotted lines *A' O' B' D'* show the members of the brake-beam in their final form and position under the system of three external forces, 2 *W*, *W* and *W*. (It may be that the pressure 2 *W* is applied at a point along the length of the post and not at its upper end, but this will not affect the analysis, since the 2 *W* would still be a force external to the frame-work or truss.) In reaching this final (dotted) position the joint *O* has moved through the distance *O O'*, or "deflection of the

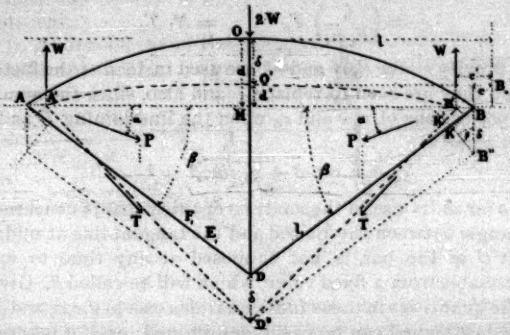


FIG. 4.

brake-beam," which we may call δ. The lower end of the post has moved through an equal parallel distance δ (since the post does not shorten), while the joint *B* has moved along a line perpendicular to the post to a new position *B'* and (similarly, *A* to *A'* on the left).

As auxiliary lines, draw *B B''* equal and parallel to δ and join *D' B''*; draw at *O'* a tangent line to the elastic curve of the bar, and verticals through *B* and *B'*. Let *O' B*$_0$ represent the unstrained length of the half-bar *O B*. Describe the short arc *B'' K'* with *D'* as center. *K'' B* may be considered a straight line and perpendicular both to *D' B'* and to *D' B''*. Also draw *B K* perpendicular to *B'' K'*.

Before application of the pressure 2 W, the deflection of the bar $A\ B$ was $= d$, $= \overline{O\ M}$, and the oblique force at its extremity B was T_o, at an angle β with $M\ B$. After application of 2 W, the oblique force acting on the extremity B' of the bar is the resultant P of the new tension T now acting in the tie-rod, and the reaction W; and the deflection of the bar is $d' = \overline{O'\ M}$. P makes some angle α (smaller than β) with $M\ B$, but need not be dealt with directly, being fully represented by its two components T and W, in their respective positions; see *Fig. 4*. It is now required to determine both T and δ.

When the bar $A\ B$ was under initial stress only, the shortening of the half bar was c, and the thrust producing it was $T_o\ cos.\ \beta$, while the force producing deflection was $T_o\ sin.\ \beta$; whereas, after the application of 2 W, the shortening of the half-bar is c', the corresponding thrust is $T\ cos.\ \beta$, and the force producing deflection is $T\ sin.\ \beta - W$.

Again, the difference between the lengths $D'\ B''$ (*i. e.*, $D\ B$) and $D'\ B'$, in other words the distance $B'\ K'$, is the excess of the elongation produced in the tie-rod by tension T over and above that due to T_o.

We are thus enabled to write [referring to equations (4), (5) and (6) for the significance of N, N_1 and R]

$$\left.\begin{aligned} &c = N\ T_o\ cos.\ \beta;\ c' = N\ T\ cos.\ \beta;\ d = R\ T_o\ sin.\ \beta; \\ &d' = R\ (T\ sin.\ \beta - W);\ \text{and}\ \overline{B'\ K'} = N_1\ (T - T_o). \end{aligned}\right\} \quad (8)$$

We also note that the distance $B\ B' = c' - c$, i. e.,

$$\overline{B\ B'} = N\ (T - T_o)\ cos.\ \beta \quad (9)$$

Projecting $B\ B'$ and $B'\ K'$ upon $B\ K$, we find that $B\ K$, which is $\overline{B\ B''}\ sin.\ \beta$, is made up of $\overline{B'\ K'}$ and $\overline{B\ B'}\ cos.\ \beta$, that is [see equations (8) and (9)]

$$\delta\ sin.\ \beta = (T - T_o)\ [N_1 + N\ cos.^2\ \beta] \quad (10)$$

In *Fig. 4* it is evident that $\overline{O\ O'}$, or δ, the deflection of middle of brake-beam, is equal to the difference between $O\ M$ and $O'\ M$; that is, between the value d, of the deflection of the bar $A\ B$ under initial cambering strain only, and that d'

of its deflection under final strain, which leads us, after noting the values in equations (8), to the relation

$$\delta = d - d' \text{ or}$$

$$\delta = R\,[W - (T - T_o)\,sin.\,\beta] \qquad (11)$$

If, now, we solve equation (10) for δ and equate the result to the right-hand member of (11), we obtain for the value of T the tension in the tie-rod [after restoring the terms represented by N, N_1, and R, as evident in equations (4), (5) and (6)]

$$T = T_o + \frac{\left(\frac{l^3}{3\,E\,I}\right) W\,sin.\,\beta}{\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\beta}{F\,E} + \frac{l^3\,sin^2\beta}{3E\,I}} \qquad (12)$$

This value for T being substituted in equation (10) we determine the deflection of the middle point of the brake-beam under the pressure 2 W to be

$$\delta = \frac{\frac{l^3}{3\,E\,I}\left[\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\beta}{F\,E}\right] W}{\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\beta}{F\,E} + \frac{l^3\,sin.^2\beta}{3\,E\,I}} \qquad (13)$$

In most ordinary cases of metallic brake-beams the last term in the denominator of (13) is so large compared with the first two that the omission of the latter occasions but slight error. Calling these two terms zero, then, we have for the case mentioned

$$\delta = \left[\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\beta}{F\,E}\right] \frac{W}{sin.^2\beta} \qquad (13a)$$

If there were originally no camber in the bar AB, we should have $T_o = O$, and the tension T for a given 2 W would be correspondingly less, but the value of δ would not be affected; in other words, the brake-beam would be no stiffer with a camber than without, except as there might be some looseness at the joints due to faulty workmanship, if there were no camber. (A conclusion different from this might perhaps be reached if the stricter considerations of "Note A" in the first part of this paper were carefully fol-

lowed out.) However, initial camber is doubtless of utility in reducing the bending action on the bar $A\,B$, making the character of the final stress upon it almost purely a thrust, and thus rendering possible some economy in material; in other words, if a brake-beam of given dimensions is to be subjected to a given pressure $2\,W$ at the middle when in service, a certain initial camber can be assigned, such that the bar becomes practically straight when the pressure is applied, *i. e.*, becomes a column, or simple compression-member. This means simply that δ is to be equal to d in *Fig. 4*, or that $d' = O$.

Making, therefore, $\delta = d, = R\,T_o\,sin.\,\beta$ from equation (8), we have

$$T_o = \frac{\left[\frac{l_1}{F_1 E_1} + \frac{l\,cos.^2\beta}{F\,E}\right]\frac{W}{sin.\,\beta}}{\frac{l_1}{F_1 E_1} + \frac{l\,cos.^2\beta}{F\,E} + \frac{l^3\,sin.^2\beta}{3\,E\,I}} \qquad (15)$$

as a special condition for this case. Having solved (15) for T_o in any numerical instance, we can then compute the corresponding value for d from equation (8), and camber the brake-beam accordingly. The final thrust produced in the bar $A\,B$ will then be $T\,cos.\,\beta$, which $= W\,cotan.\,\beta$ [since d' is to be zero; see equation (8)].

[NOTE B.—The expression for T in equation (12) is identical with that derived by G. P. Ritter, C.E., who has used Castigliano's method of Least Work, in a thesis on the metallic brake-beam, written during his Senior year ('96–'97) in the College of Civil Engineering at Cornell University. Mr. Ritter applied this method as adapted by Castigliano to the case of a framework under initial stress.

This identity was to be expected, since in both treatments the consideration of shearing stresses is omitted and the bending moment in the bar $A\,B$ is assumed to be independent of the thrust component at the extremity.

The present writer has also applied a modification of Castigliano's other theorems, involving the "derivatives of internal work," and obtained a value for δ the same as that given in equation (13). Castigliano gives no direct method

for finding displacements of joints in a framework in which there are strains before loading; but if we write out the expression for internal work as due to the *excess* of each final stress over its initial value, the function so formed can be employed for purposes of differentiation, in obtaining displacements, which will be those occurring during the application of the external forces, *after the initial strains are set up*.]

Borrowing a numerical example from Mr. Ritter's thesis (see note B), let us apply equation (13) for deflection, to a steel brake-beam in which the bar or compression-member is a hollow cylinder, whose outer diameter is 2 inches and inner 1·62 inches, and length = 60·5 inches, with round tie-rods of 0·875 square inch sectional area, the angle β being 18° 22′, and the load 15,000 pounds.

That is, using the units inch and pound, we have $l = 30{\cdot}25$, $l_1 = 31{\cdot}88$, $F = 1{\cdot}08$, $F_1 = 0{\cdot}875$, $I = 0{\cdot}447$, $W = 7500$, and may take $E = E_1 = 28{,}000{,}000$; on substitution of which in equation (13) we obtain

$$\delta = 0{\cdot}16 \text{ inch};$$

a result which, to quote Mr. Ritter, "is almost exactly what tests show for such a beam."

The Jacques Carbon Battery.

By John W. Langley.

The experimental portion of the investigation of this subject was performed by two students, Messrs. H. S. Rosewater and W. H. Oldham, of the Case School of Applied Science, Cleveland, O., who made it the subject of a thesis, which is here partly reproduced. Some of the tables of readings have been omitted, but their results are represented graphically by curves.

Among those who have been attempting the direct production of electricity from carbon is Dr. W. W. Jacques, of Boston, who startled the scientific world and general public

recently by his broad assertion that he had invented a process of making electricity directly from coal, and that his process was practicable and would revolutionize existing methods. He claimed for it an efficiency of 32 per cent. instead of the present value of only 6 per cent. or 8 per cent.

His apparatus, as embodied in a patent, consists of a closed furnace, which heats an iron pot about 6 inches in diameter and 2 feet deep, which is filled with caustic potash or soda, the alkali being kept in a melted state by the application of heat. The following sketch (*Fig. 1*) will serve to show the general character of his battery. In this melted

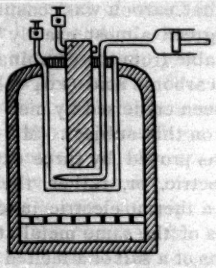


FIG. 1.

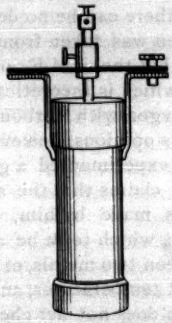


FIG. 2.

alkali is suspended a rod 3 inches in diameter and 20 inches long, made of coal compressed into sticks of the above size and baked so as to expel the included gases. This forms one plate or electrode of the battery, and is the consumable element.

In order to accelerate the action of the battery a supply of air is to be forced through an iron pipe, which terminates in a rose nozzle. Thus the air keeps the melted hydrate in constant agitation and at the same time supplies oxygen, which Jacques claims is necessary for the chemical action. With a cell of this size a current of 150 amperes at an E.M.F. of one volt is obtained.

A test made on a battery of 100 cells, each 12 inches deep and 1½ inches in diameter, showed that thirty 16-candle-power lamps were maintained for eighteen and three-quarter hours at full incandescence, the average E.M.F. being 90 volts, current 16 amperes, consuming eight pounds of carbon in the pots. The report claimed that "the actual electrical energy obtained from the carbon consumed in the pots was 82 per cent. of the theoretical." This efficiency, however, means nothing and is quite misleading, as it does not include the carbon consumed outside the pot to heat it.

Much discussion has arisen as to the cause of the current. Jacques says "that the electric current is due to the chemical combination of the oxygen of the air with the coke (carbon) there can be no doubt. Qualitative tests showed that oxygen was taken from the air, that carbon was consumed, and that the E.M.F. obtained agreed almost exactly with that which is theoretically obtainable from the combination of oxygen with carbon to form carbonic acid (1·04 volts)."

His opinions, however, have been criticised by men who have experimented a great deal on this subject. Mr. C. J. Reed claims that the action is, as proved by three experiments made by him, thermo-electric, or, rather, thermotropic, which term he applies to a thermo-electric junction between two metals, or two pieces of the same metal at different temperatures, and a solution of a salt or a melted salt, which does not act chemically on the metal immersed in it.

This paper will endeavor to show that no new theory need be put forth to explain the action of this battery, but only an old one applied. With the view of finding the correct reason for this extraordinary current, tests were made in which the following apparatus was used:

A A furnace.
B An iron pot.
C A pyrometer.
D An air blast.
E A gas burner.
F Various instruments to be described later.

The furnace was built of brick and contained the pot packed around with fragments of fire brick. A large multi-

ple gas burner, whose gas supply could be very accurately regulated, served as the source of heat, and by it the temperature of the pot could be quite exactly brought to any desired point and maintained nearly constant.

B, the Pot. The pot was made 12 inches in length, of 4-inch steam pipe, with a cap over its lower end. To its upper end were riveted two right-angled irons, which served as handles for the pot and also as one of the terminals of the electric circuit, as shown in *Fig. 2.* As the pot was too short to project through the cover of the furnace, a sheet iron sleeve was made to fit over the pot and between the upright handles. Over these two handles a horizontal iron bar was fastened with set screws. Through the center of the bar a collar passed, which held, insulated from it, a brass tube, to the upper end of which a binding post was fastened, the lower being slotted so as to hold either of the various rods to be experimented upon.

C, the Pyrometer. The temperature of the melted alkali was measured by a pyrometer of the Siemens type, which, as is well known, depends on the variation of the resistance of a platinum wire with its temperature, the wire being included in an electric circuit. The instrument consisted of a piece of ¾-inch iron pipe about 24 inches long, with a plug in its lower end. In the bottom of the pipe, and insulated from it by sheet asbestos, was a coil of platinum wire wound around a clay pipe stem, one end of the coil passed up through the stem, the other on the outside of the pipe stem and separated from the iron pipe by the asbestos. Both ends were fastened to copper leads at the top of the pipe.

Thus keeping the amperes constant in the coil, the volts, which varied directly with the resistance, which, in turn, varied directly with the temperature, were made to read the temperature by being properly calibrated. This was done by having an accurate mercurial thermometer immersed with the pyrometer in an oil bath, readings being taken simultaneously. The thermometer used read to 550° F. The current was kept constant by means of a rheostat at .25 amperes during the entire calibration, and also during all the experiments which follow. Two calibrations were made up to

350° C., at which point the oil took fire. A curve was plotted from these readings with volts and temperature as axes, and a straight line drawn through the majority of the points. A check was made on this line by finding the voltage at which zinc melted, and knowing the temperature a new point was found which agreed very closely with the line.

Compressed air was admitted to the pot by a ¼-inch iron pipe, which descended to the bottom and terminated in numerous small orifices.

The circuit was arranged as in *Fig. 3*. The instruments used were two ammeters, one reading to thousandths and the other to thirtieths of an ampere; also a voltmeter reading to thirtieths of a volt. A battery and rheostat were added for the pyrometer circuit.

By means of a two-point switch the voltmeter could be

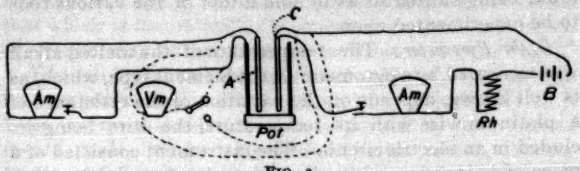


FIG. 3.

connected either with the pyrometer circuit or with the pot circuit, thus giving, in the first case, the temperature, and in the second the E.M.F. of the pot.

In *Fig. 3*, *A* is the carbon, iron or copper rod, *B* a battery, *C* the pyrometer, and *R h* a variable resistance. The readings were made in the same order in all of the experiments. (1) The pot voltage was read on open circuit and marked "Volts" in the diagrams. (2) The pot amperes read when the ammeter alone was in the circuit, designated by "Amps" in the diagram. (3) The pyrometer current was adjusted to .25 amperes, and the voltage read and reduced to its temperature equivalent, designated as "Temp" in the diagrams.

In order to avoid ambiguity in the following diagrams, the plus and minus signs are such that when the carbon, iron or copper rod is connected to one terminal of the out-

side circuit and the pot to the other terminal, the flow of current from the rod is the same as though these signs were applied to an ordinary liquid battery having its zinc pole marked "minus." The pot was grounded and, therefore, at O potential, always.

Seven experiments were made in the following order:

1 A copper rod without the air blast.
2 A copper rod with the air blast.
3 An iron rod without the air blast.
4 An iron rod with the air blast.
5 A carbon rod with the air blast.
6 A carbon rod without the air blast.
7 A carbon rod without the air blast, but with sodium nitrate added to the melted caustic soda in the pot.

All the materials used were of ordinary commercial quality, because these only could be economically used in a practical battery; therefore no attempt was made to employ chemically pure materials, as would have been the case if these experiments had been made in the interests of pure science instead of electrical engineering.

In experiment No. 1 a ½-inch copper rod was used, which was brightened before using, but which became coated with a dark scale, copper oxide, which scale was not disturbed for experiment No. 2.

Referring to *Plate I*, the curves of volts and temperature approach and recede from each other, *i. e.*, when the temperature goes up the volts drop, and when the temperature falls the volts rise; the same being true of the amperes, as shown by curve *V*, of *Plate VIII*.

In experiment No. 2 the same copper rod was used, and just enough air to keep the alkali from splashing. *Plate II*, together with curve *VI* of *Plate VIII*, show the results. The same general outline is observed, the volts falling as the temperature rises, and the reverse. The ampere curve, *Plate VIII*, curve *VI*, acts similarly to that of *Plate II*, except at the end of two hours and twenty-five minutes it rises to the maximum positive reading attained by any of the curves; in this case both curves become negative twice.

In experiment No. 3 a ½-inch iron rod was used, thus

making with the iron pot a hypothetical battery in which both electrodes or plates were of the same metal (which would exclude ordinary galvanic action), still, an E.M.F. was

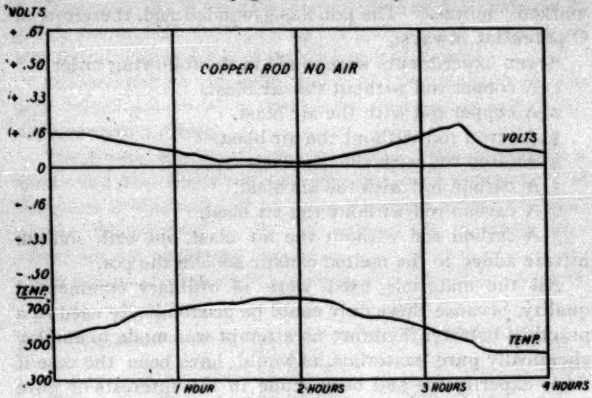


PLATE I.

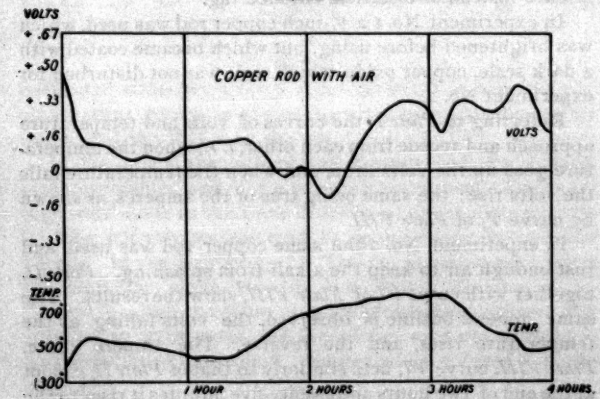


PLATE II.

created and a current circulated, as shown in *Plate III*, and in *Plate VIII* curve *VII*. The latter shows the general characteristics of thermo-electric action, the curve going

within ten minutes from a + value to — 4·5 amperes, the maximum negative value attained by the amperes.

Experiments 4, 5 and 6 show the same general relation

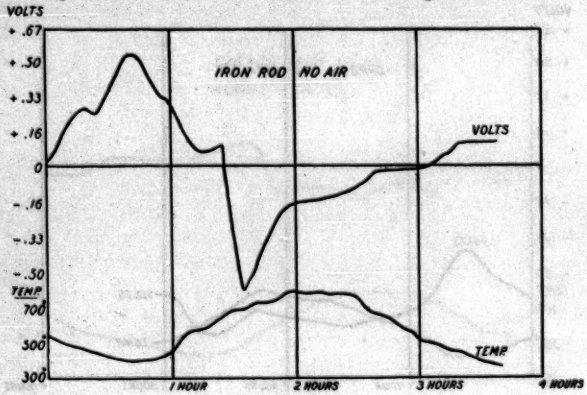


PLATE III.

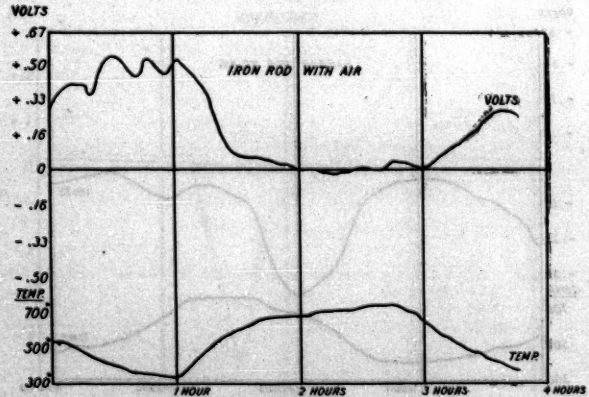


PLATE IV.

between rise of temperature and fall of volts, and it will be noticed that the E.M.F. produced by carbon against iron is not materially greater than that of iron against iron, as

shown by *Plates III* and *VI*. This is directly opposed to Mr. Jacques' theory, but to give his hypothesis every chance and to favor chemical action as much as possible, experiment

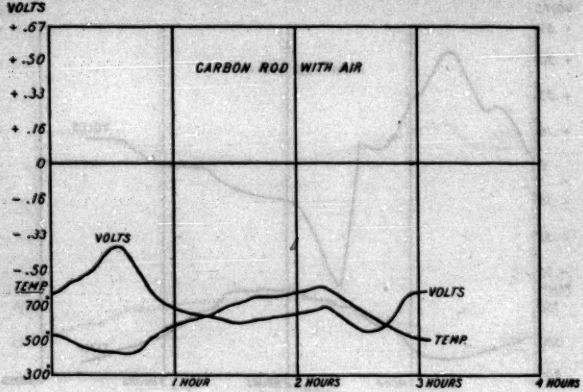


PLATE V.

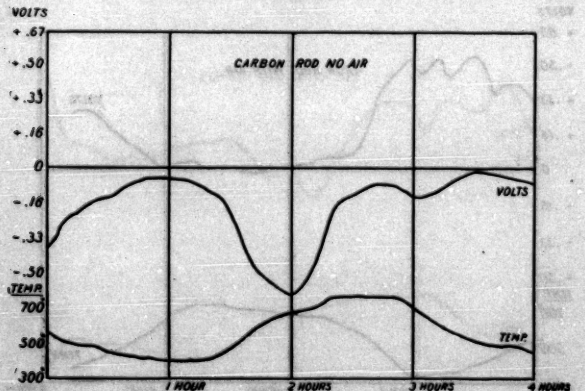


PLATE VI.

No. 7 was instituted, in which some sodium nitrate was added to the melted alkali in the pot. It would seem that if the voltage produced was caused by the oxidation of car-

bon, as Jacques asserts, the nitrate acting at a red heat ought to develop it, but *Plate VII* shows a diminished, not an increased E.M.F.

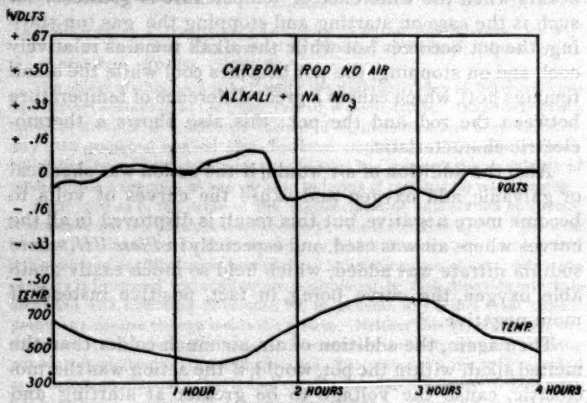


PLATE VII.

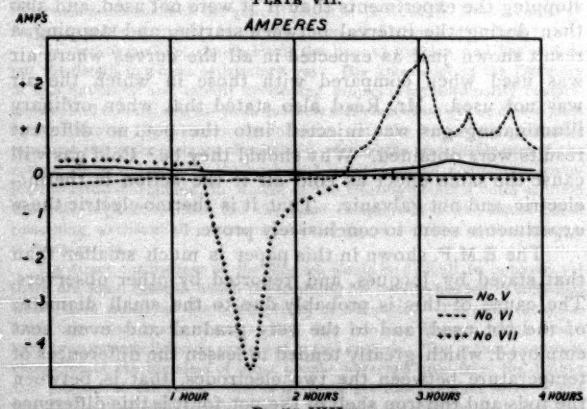


PLATE VIII.

That these experiments show the cause of the current to be thermo-electric there can be no doubt. In the first place the general appearance of the curves plotted is that of

characteristic thermo-electric curves by their sudden changes in magnitude and direction. Then the maximum voltage occurs when the difference of temperature is greatest; for such is the case on starting and stopping the gas (on starting, the pot becomes hot while the alkali remains relatively cool, and on stopping, the pot becomes cool while the alkali remains hot), which causes a great difference of temperature between the rod and the pot; this also shows a thermo-electric characteristic.

Also the addition of air would, if the action was chemical or galvanic, add oxygen and cause the curves of volts to become more negative, but this result is disproved in all the curves where air was used, and especially in *Plate VII*, where sodium nitrate was added, which held so much easily available oxygen, the curve being, in fact, positive instead of more negative.

Then again, the addition of air, air much colder than the melted alkali within the pot, would, if the action was thermo-electric, cause the voltage to be greater at starting and stopping the experiments than if it were not used, and also than during the interval between starting and stopping, a result shown just as expected in all the curves where air was used when compared with those in which the air was not used. Mr. Reed also stated that when ordinary illuminating gas was injected into the pot, no different results were obtained. Why should they be? Cold gas will cause the same effect as cold air if the action is thermo-electric, and not galvanic. That it is thermo-electric these experiments seem to conclusively prove.

The E.M.F. shown in this paper is much smaller than that stated by Jacques, and reported by other observers. The cause of this is probably due to the small diameter of the pot used, and to the very gradual and even heat employed, which greatly tended to lessen the differences of temperature between the two electrodes, that is, between the rods and the iron shell of the pot, for it is this difference only which causes the E.M.F. observed, according to the views put forth in this paper.

Case School of Applied Science,
Cleveland, O., July 1, 1898.

BOOK NOTICES.

The Phase Rule; a Treatise on Qualitative Chemical Equilibrium. By Wilder D. Bancroft. *The Journal of Physical Chemistry*, Ithaca, N. Y. Large 8vo. Pp. 252. Price, $3.

The object of this book is to classify the different types of heterogeneous equilibrium according to the phase rule of Willard Gibbs. Since only qualitative equlibrium is considered, the use of mathematics has been unnecessary; the graphical method alone has been employed. The result is a book which can be read profitably by anyone who has grasped the possibility of representing a function of one variable in terms of rectangular co-ordinates.

Some clue as to the sense of the displacement of equilibrium by change of pressure and temperature was necessary; this is supplied by the "theorem of Le Chatelier," that is, that the change which occurs when heat is added to a system in equilibrium is associated with the absorption of heat; when the pressure is increased the equilibrium is displaced in that direction which is identified with reduction in volume, or, in general, any action from outside produces a reverse change inside the system. Neither this generalization nor the phase rule is proved: the book is concerned entirely with the working out of their applications to the phenomena. This omission is not to be regarded as a defect in the work, for it lies outside its plan. Further, Gibbs' work has been made accessible in a German translation by Ostwald,* and the thermodynamic treatment of the generalization of Le Chatelier is to be found in various text-books, notably in the recent remarkable work of Duhem.†

The author has kept rigidly inside the lines of his plan, and has worked out the details in a most satisfactory way. His knowledge of the literature of this extensive and rapidly developing subject is extraordinarily comprehensive and minute, and the book contains many facts that will be new to most of us. New to the reviewer, for instance, were the interesting qualitative proofs of the vapor pressure of metals (p. 16) and the remarkable case of the system composed of hexa-chlor α keto γ-R-pentane and penta-chlor-mono-brom-α-keto-γ-R-pentane, in which, at the freezing-point, a solid solution invariably separates, which has the same composition as the liquid phase remaining, so that at all concentrations the liquid solidifies without change of temperature.

The direct conciseness of the English would be difficult to improve, yet there are some cases in which the straining for brevity has led to omissions which have destroyed the intelligibility of a sentence. The same cause has led in one or two instances to crowding data into one diagram which would have been more judiciously presented in two or three. The author's constant exposition of the blunders of other people detracts a little from the dignity and interest of the book. One is likely to get the idea that some of the remarkable men who have worked in this field, notably Ostwald, have distinguished themselves chiefly by making a series of absurd mistakes. One

* "Thermodynamische Studien, von Willard Gibbs." Leipzig, Engelmann.

† P. Duhem, "Traité de Mécanique Chimique," [I], 181.

must admit, however, that the criticism (p. 100) of Ostwald's famous proof that if two liquid phases are in equilibrium they must both emit the same vapor* is incisive. It will startle those of us who, like the reviewer, have for years accepted the proof as sound.

The reviewer notes with pleasure the adoption and consistent use of the nomenclature of Trevor for the different types of heterogeneous equilibrium. Of course, anyone who is interested in the development of chemical theory must have the greatest admiration for the brilliant work of Bakhuis Roozeboom, yet the fact remains that his nomenclature was merely a makeshift and the science will be advanced by its replacement by the terminology of Trevor, which leaves little to be desired in point of accuracy and conciseness.

In conclusion, it may be said that the defects of the book are trifling and its merits of a high order. It may be read with profit by chemists, no matter what particular sub-division of the science they cultivate. The appearance of such a book in English should do much toward ending the anomalous state of things in which some chemists refuse to concern themselves with topics like chemical equilibrium and the speed of reactions, on the curious ground that these subjects belong to the province of physics.

The book has been appreciatively reviewed by Roozeboom† and by Le Chatelier.

ROBERT HART BRADBURY.

Stones for Building and Decoration. By George P. Merrill, Curator of Geology in the United States National Museum. Second Edition, revised and enlarged. New York: John Wiley & Sons. 1897. Price, $5.

The present edition differs from the first, issued in 1891, principally in the addition of some fifty pages upon the onyx marbles or travertines, for which reference is made to the author's paper in the annual report of the United States National Museum for 1893.

The added portion, like the rest of the book, is beautifully illustrated. Amongst the photographic reproductions is one showing the annual outcrops of onyx marbles in Lower or Baja California.

The author gives a table showing the composition and physical characteristics of onyx marbles from Egypt, Persia, Arizona, California, Mexico and other localities, and describes at some length the ancient and modern uses of these stones and the various foreign and American localities. J. C. T.

NOTES AND COMMENTS.

ARTIFICIAL DIAMONDS.

A new process for producing artificial diamonds has been experimented on successfully by Dr. Quirino Majorana (*Rendiconti della R. Accademia dei Lincei*). The present method consists fundamentally in heating a piece of

---

Lehrbuch der Allgemeinen Chemie, [1] P. 645.

†*Journal of Physical Chemistry*, [1] p. 559 (1897).

carbon by the electric arc, and then submitting it to a violent pressure by means of a small plunger actuated by a piston, on which a pressure of 5,000 atmospheres was suddenly developed by explosion. When a sufficiently strong cylinder had been constructed to withstand this enormous pressure, the experiment produced a black mass consisting largely of graphite and amorphous carbon. On employing Berthelot's method to isolate the diamonds if they existed, small microscopic crystals were obtained, mostly black and opaque, but which exhibited all the properties of true diamonds, notably in their manner of burning at a high temperature. The conclusion drawn from these experiments is that pressure and heat are alone sufficient to transform amorphous carbon into the crystalline or diamond form, and that the presence of a metallic solvent, as in Moissan's experiments, is not essential to the transformation. W.

PENETRATING POWER OF LIGHT BODIES.

A curious illustration of the power of light matter to perforate more substantial substances when driven at a high velocity is stated by the *Engineer* to have occurred in the Royal Arsenal a few days ago. In the course of experiments on firing gas in mines, conducted by Captain Cooper Key, R.A., under the Home Office, a special gun is employed to do duty for a bore-hole with a charge of high explosive, and pressed cylinders of raw dry clay, 3 inches long and 1⅜ inches in diameter, are used to represent tamping. These "shots" are made to act in various mixtures of air, coal-dust, gas, etc., and to stop the course of plug, etc., eventually, a cast-iron target plate, 1 inch thick, was placed 25 feet in front at an angle of 45°, in order to break up everything into dust and throw it upwards. After three or four shots with this arrangement, the clay plug, weighing 7½ ounces, perforated the inch iron plate, and the hole thus made has been steadily extended since. The familiar tallow candle passing through a door must hide its head before a 7½-ounce plug of clay perforating an iron plate an inch thick at an angle of 45°. Doubtless the velocity must be tremendous. It is pointed out that the velocity for a hard cylinder of this weight and size to cut through an inch of wrought iron at 45° would be over 1,800 foot-seconds. With cast iron and clay and the three or four repeated blows, everything is so greatly altered that there is little more to be said than that the effect is remarkable and unexpected. W.

WELSBACH'S NEW ELECTRIC INCANDESCENT LAMPS.

There have been many rumors afloat of late respecting the latest inventions of Dr. Auer von Welsbach, which are directed towards the improvement of the electric glow lamp in respect both of duration of service and light efficiency. In both these directions it must be admitted there is room for substantial betterment, and Dr. Welsbach will deserve well of the public and will reap a substantial reward should he succeed in realizing the expectations he has raised.

The publication of certain patents recently granted to Dr. Welsbach suffices to give a general outline of the direction in which he is working.

The patents here alluded to describe two kinds of glow-bodies for use in incandescent electric lamps. The first is a fine filament of osmium of a peculiar form. Osmium is one of the metals of the platinum group, generally found in nature in the form of flat irregular grains, associated with iridium in the mineral called osmiridium. It may be obtained in the pure state by a chemical method of separation, in which advantage is taken of the fact that the tetroxide, which is readily formed by heating the metal in the air, is a volatile compound. It must be prepared, however, with great care, because of the extremely poisonous character of its fumes.

The second glow-body described is one formed of "thoria" and earth-metal oxide which is already largely employed in the preparation of the well-known Welsbach incandescent gas mantles.

Referring to the osmium filament, the basis of its selection as the substitute for the carbon filament is the claim made by the inventor that it does not volatilize at the highest attainable temperature when confined in a vacuum or surrounded by a reducing atmosphere.

A serious difficulty with the carbon filament in the ordinary electric glow-lamp, is the rapid darkening of the glass by the deposit on the inner surface of the glass bulb, of carbon volatilized by the heat of the current, or mechanically worn off by its passage. From this cause the light emission of the common electric glow-lamps is rapidly reduced, and it occasionally happens that they must be discarded long before the filament itself is broken. It is principally to avoid this defect of the carbon filament that Welsbach has had recourse to osmium. The present difficulties attending the production of his osmium filaments, however, are so great that it appears gravely doubtful if the method can be made commercially valuable.

The fact that it is impracticable to fuse osmium (and on this great infusibility its value for Welsbach's purpose depends) makes it impossible to obtain it in any other form than that of a powder which cannot be united into a solid mass by pressure and then drawn into wire. It becomes necessary then to obtain the osmium filament by indirect means, and for this purpose Welsbach deposits it on a fine platinum wire maintained in an atmosphere of hydro-carbon vapor mingled with water vapor (*sic*); and the platinum wire being heated to incandescence in this atmosphere by the electric current, small quantities of the vapors of osmium tetroxide are blown in from time to time. The result is that a thin layer of metallic osmium is deposited on the platinum wire. This operation, it would seem from the published account, is a slow and exceedingly delicate one, for the deposited film must be quite uniform to answer the purpose, since any irregularity in the deposit would affect the uniformity of its resistance and yield a light more brilliant in spots. Another method of obtaining the deposit is described, which consists in drawing the fine platinum wire through the solution of an osmium salt, and then glowing it in a vacuum. To obtain the film in the required condition, by this method, only an infinitely thick layer must be formed at a single operation, so that it must be repeated many times (100 times at least) to obtain the needful uniformity in the superposed layers. Neither of these methods, therefore, seem to present much promise of success on the commercial scale.

A more practical method suggested is to use vegetable or animal fibers as the foundation for the osmium coating. A liquid pulp is made by mixing the

finely comminuted osmium oxide and the fibers with sugar solution or other organic cementing material, and, after drying and cutting into the required shape for the lamp, it is glowed slightly in an atmosphere of reducing gas. By this and slightly modified methods, a carbon skeleton is formed carrying a certain quantity of unconsolidated osmium. These methods appear practical; but it will be observed that the resulting filament is not a pure osmium filament, but one consisting largely of carbon, and hence open to the same objections as the common carbon incandescent lamps, besides being vastly more costly.

The second proposal of Welsbach is the thoria filament.

This substance, as above remarked, is one of the rare earths largely used in the manufacture of the Welsbach gas mantles, and is known to possess light-emitting qualities of a high order.

To obtain this filament the inventor employs an extremely thin platinum wire (0·02 millimeters in diameter) approximately as thin as a single fiber of the silk cocoon, and draws this successively through elastic cheeks which are kept moistened with a solution of salt of thorium. After each drawing the wire is glowed, and the operation must be repeated, as in the one above described, many times, in order that the resulting coating shall have the necessary permanency.

The resulting thread, then, is a platinum core, surrounded by a dense incrustation of thoria. The heat-resisting qualities of the incrusting oxide are said to be so great that the platinum wire within may be melted without affecting it, while the amount of heat radiated from the brilliantly luminous thoria is comparatively small. With the current intensity employed for ordinary illumination, however, the platinum core is not melted, the explanation being that the greater part of the heat energy imparted to the platinum is transformed by the fire-proof encrusting material into light; the intense power of the coating to emit light withdraws and transforms much of the heat of the metallic conductor into light.

The above description gives merely an outline of the several methods set forth in Welsbach's recent patents. In view of the great expectations raised by the reports of his remarkable laboratory work, it must be confessed that the outcome is a disappointment. While the methods proposed are ingenious, they seem to be altogether too delicate to be capable of being commercially applied, and they are undoubtedly so costly as to place serious competition with the cheap electric glow lamp, with which we are familiar, out of the question. W.

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1897.

Mr. Richard P. Rothwell, C.E., the well-known mining engineer, and editor of the *Engineering and Mining Journal*, has just issued Volume VI of the valuable statistical publication, "The Mineral Industry," giving the complete statistics of the production of minerals and metals in the United States in 1897.

From this excellent compendium it appears that the total value of the mineral products of the United States in the last calendar year was $678,966,644.

The principal items making up this magnificent total were: gold, 2,864,576 ounces, valued at $59,210,795; silver, 56,457,292 ounces, of the value of $33,755,815; copper, 510,190,719 pounds, valued at $56,325,055; lead, 197,718 tons, valued at $11,784,093; zinc, 100,387 tons, of the value of $8,271,889; iron, 9,652,680 tons, valued at $92,677,312; coal, all forms, 200 259,243 tons, worth, in round figures, $250,000,000; clay products, various kinds, valued at $60,000,000; crude petroleum (in round figures), 8,000,000 barrels, of the value of $44,804,962; natural gas of the value of $10,000,000; building stone of the value of $30,000,000.

The significance of these figures will perhaps be best appreciated by comparison with those of European countries. On this point, the following statement, made at the close of the year 1896, holds equally good for the year 1897, viz.: "The total value of the output in 1896 (which had an estimated value slightly less than that of 1897) exceeded that of the mineral and metal production of all Continental Europe, and nearly doubled that of the United Kingdom, the value of whose mineral output in 1896 was, in round figures, about $340,000,000, while that of Germany was about $300,000,000, that of France about $110,000,000, and that of Belgium about $100,000,000."

Certain items in the statistical table accompanying this volume have a peculiar interest. Thus, the increase in the production (about 230,000 ounces, about $7,000,000) over that of 1896, although considerable, is not so large as would be anticipated from the large output of the Klondike region, for the reason that by far the larger portion of the yield of that great northwestern country is obtained from British-American territory. Also, the production of pig iron and coal in 1897 was the largest in any single year in the history of the United States. The production of silver exhibits a decrease as compared with the figures of the year previous of almost exactly 2,000,000 ounces, which is attributed to the heavy decline in the market price of silver, which compelled the closing of a considerable number of heretofore productive mines, and incidentally also exerted a deterrent influence upon the development of new mines.

The production of aluminum in 1897 exhibits a large comparative increase, being 4,000,000 pounds ($1,400,000), as compared with 1,300,000 pounds ($520,000) in 1896. This increase is ascribed in part to the reduction in the price of metal and in part also to the development of a considerable export trade.

The new product, calcium carbide (from which acetylene gas is made), appears in the tabulation with an output estimated at 860 tons, valued at $48,000. The growth of this industry, as these figures indicate, is thus far much less rapid than the sanguine expectations of those interested in the new illuminant led the public to expect.

The heavy chemical industries represented by such staple articles as soda and sulphuric acid exhibit a gratifying increase, the value of the first-named product rising from about $3,500,000 (in 1896) to $5,750,000 (in 1897), and the latter from $17,250,000 to $21,500,000.

The foregoing facts and figures make a most impressive picture of the annual increment to the wealth of the nation from the development of its mineral resources.

W.